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THE SCIENTIFIC MONTHLY

JULY, 1921

THE HISTORY OF CHEMISTRY*

By Professor JOHN JOHNSTON

YALE UNIVERSITY

CHEMISTRY is the science of the ultimate composition and constitution of matter, of the mutual reaction between two or more substances, and of the influence of factors such as change of temperature, pressure, or extent of surface upon the stability of a substance and its relation to other substances. The chemist studies the great diversity of substances, organic and inorganic, which we see around us; he analyzes these substances, ascertains their composition, and builds them up again from their components; he investigates their behavior with respect to change in external conditions and in relation to other substances. He learns how, not merely to imitate a substance occuring naturally, but to make the identical material artificially and to discover new substances superior in usefulness to those found in nature; and he considers how useful substances may be produced more economically from the raw materials available. The study of chemistry is slowly yielding information as to the nature of biological processes of importance to every one and so is assisting to retain health and to control disease. Indeed our material well-being and comfort depend in large part upon a fundamental knowledge of chemical processes and how to control them; and continued progress along these lines will be limited only by the rate at which we extend our knowledge of fundamentals, what chemistry has achieved being but a fraction of what it may do for us.

The great practical achievements of chemistry are comparatively recent, almost entirely within the last sixty years, quite largely indeed within the present century. They are so manifold that it would not be feasible in the space allotted even to mention a fraction of them; consequently I have endeavored only to sketch in general outline, as free from technicalities as possible, the development of the main funda-

*A lecture delivered at Yale University, March 25, 1920, the second of a series on the History of Science under the auspices of the Yale Chapter of the Gamma Alpha Graduate Scientific Fraternity.

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mental principles of chemistry, and even in this have been forced to omit much that is important.

Development of the Idea of Chemical Elements and of Their Mutual Relationship

Two hundred years ago, at which time the classical mathematics had already reached a high state of development, chemistry had not begun to be a science, nor even an art; it was more or less of a mystery, in which language was used to conceal the fact that there was no thought—as it still is used by some today. Boyle in "The Sceptical Chymist," first published in 1661, refers to the vagueness of the ideas then current in the following terms:[1]

> The confidence wherewith chymists are wont to call each of the substances we speak of by the name of sulphur or mercury, or the other of the hypostatical principles, and the intolerable ambiguity they allow themselves in their writings and expressions, makes it necessary for me . . . . to complain of the unreasonable liberty they give themselves of playing with names at pleasure . . . . I cannot but take notice, that the descriptions they give us of that principle or ingredient of mixt bodies, are so intricate, that even those that have endeavored to polish and illustrate the notions of the chymists, are fain to confess that they know not what to make of it either by ingenuous acknowledgments, or descriptions that are not intelligible . . . . Chymists write thus darkly, not because they think their notions too precious to be explained, but because they fear that if they were explained, men would discern, that they are far from being precious. And, indeed, I fear that the chief reason why chymists have written so obscurely of their three principles, may be, that not having clear and distinct notions of them themselves, they cannot write otherwise than confusedly of what they but confusedly apprehend; not to say that divers of them, being conscious to the invalidity of their doctrine, might well enough discerne that they could scarce keep themselves from being confuted, but by keeping themselves from being clearly understood . . . . If judicious men, skilled in chymical affairs, shall agree to write clearly and plainly of them, and thereby keep men from being stunned, as it were, or imposed upon by dark and empty words; it is to be hoped, that these (other) men finding, that they can no longer write impertinently and absurdly, without being laughed at for doing so, will be reduced either to write nothing, or books, that may teach us something, and not rob men, as formerly, of invaluable time; and so ceasing to trouble the world with riddles or impertinencies, we shall either by their books receive an advantage, or by their silence escape an inconvenience.

And again,[2] showing that he had no great opinion of their methods:

> Methinks the Chymists, in their searches after truth, are not unlike the navigators of Solomon's Tarshish fleet, who brought home from their long and tedious voyages, not only gold, and silver, and ivory, but apes and peacocks too: for so the writings of several (for I say not, all) of your hermetick philosophers present us, together with divers substantial and noble experiments, theories, which either like peacock's feathers make a great

[1] The Sceptical Chymist, Everyman's Edition, pp. 113-6.
[2] Op. cit. p. 227.

show, but are neither solid nor useful; or else like apes, if they have some appearance of being rational, are blemished with some absurdity or other, that when they are attentively considered, make them appear ridiculous.

The general belief of the alchemists appears to have been that there is a primordial matter which, when combined with more or less of one or more of their four so-called elements or principles—fire, air, earth and water—becomes apparent to our senses as the various substances we know; in other words, that matter is the carrier or embodiment of certain qualities which can by appropriate treatment be enhanced or attenuated. It is juster to look upon the alchemists' so-called elements as qualities—such as hotness, coldness, dryness, wetness—typified by the things named, though no single quality would suffice for a single element, as each alchemist tended to endow his elements with such attributes as suited his immediate purpose. In addition to these four elements some made use also of the "hypostatical" (fundamental) principles—salt, sulphur and mercury, which again may be interpreted as typifying fixity in the fire or incombustibility, combustibility, volatility and metallic lustre, respectively. Such views lead one directly to believe in the possibility of transmutation, of changing base metal into gold; for to achieve this, it would be necessary only to effect a suitable change in the proportions of the elemental qualities, a possibility which therefore seemed far from hopeless or absurd.

It is clear that no great progress in chemistry as a science could have been made, so long as such false views prevailed. And indeed the alchemists contributed nothing to the real philosophy of chemistry, although they did discover—by chance, more or less—a few useful substances, such as sulphuric acid (oil of vitrol) and tartar emetic, some of which found application as drugs. For one of the tasks they set for themselves was to find the elixir of youth, a quest along with which went a belief in the efficacy of doses of the strangest mixtures; indeed, an ingenuous person examining the present-day official pharmacopeias might well be led to think that the alchemists continued to flourish and to be powerful until very recent times.

The overthrow of this false philosophy was begun by Robert Boyle, in his "Sceptical Chymist." He endeavored to distinguish the qualities of a substance from its composition, and enunciated views with reference to the difference between elements and compounds which are still held. Thus he writes: "I must not look upon any body as a true principle or element, but as yet compounded, which is not perfectly homogeneous, but is further resoluble into any number of distinct substances, how small soever." "I mean by elements, as those chymists that speak plainest do by their principles, certain primitive and simple, or perfectly unmingled bodies; which not being made of any other bodies, or of one another, are the ingredients of which all those called

perfectly mixt bodies are immediately compounded, and into which they are ultimately resolved."[3]

It is difficult to picture the exact status of knowledge of chemical art at that period, partly because the alchemists commonly described their experiments in vague terms, partly because their false theories prevented them from discovering all the pertinent facts and led them to misinterpret much of what they did observe. For instance, the doctrine of the indestructibility of matter—that the total weight of a system remains unaffected by chemical changes taking place within it—now regarded as axiomatic, was not definitely formulated; the material nature of air had not yet been recognized, nor had gases been really differentiated; the process of combustion was not understood, and analytical methods hardly existed.

Boyle's views gained ground very slowly, but the progress of chemistry was hindered for a century by a false theory, the so-called phlogiston theory. According to this view, there is an inflammable principle—phlogiston—which escapes when a substance is burned. For instance, when a metal is burned, phlogiston escapes and a calx or earth remains; on which basis the metal is a compound of calx plus phlogiston, whence it would follow that in order to regenerate the metal, phlogiston must be supplied to the calx by heating with some substance (such as carbon) rich in phlogiston. This theory emphasized the fundamental similarity of all combustion processes, and to that extent was a good and useful hypothesis; but the picture it presented is almost the exact inverse of the real facts, for we now know that a metal in burning actually unites with oxygen, that the calx or oxide weighs more than the metal, and that the system as a whole has lost energy, mainly in the form of heat—all of these changes having to be reversed in order to regenerate the metal from the oxide. The phlogiston theory, despite its falsity, continued to prevail for a century, during which time it befogged the whole subject and paralyzed the advance of chemical philosophy; the net result being that, until nearly the end of the eighteenth century, the subject was as little clear as it had been a hundred years before, although it had in the meantime been enriched by many new observations of importance, and progress along experimental lines had been quickened by improved technique. This prevalence of a false theory, which hindred progress so greatly, leads one to wonder if some of the hypotheses now commonly accepted do not have a similar inverse relation to the real facts, as was the case with the phlogiston theory; it is this type of question which the promoters of the theory of relativity are in effect asking with respect to our fundamental physical ideas.

Another mistaken notion was the material nature of heat. The fact

[3]Op. cit. p. 187.

that flames issue from burning bodies led to the view that they were material objects; and so fire was regarded as one of the elements. Even after the overthrow of the ancient ideas of combustion, it was believed that heat, or caloric as they termed it, though devoid of weight, was a substance—an imponderable, in the same category as light and electricity.

Thus, even as late as 1848, in a very interesting "Manual of Chemistry"[4] the author writes:

> The first part comprehends an account of the nature and properties of Heat, Light and Electricity—agents so diffusive and subtile that the common attributes of matter can not be perceived in them. They are altogether destitute of weight; at least, if they possess any, it cannot be discovered by our most delicate balances, and hence they have received the appellation of Imponderables. They cannot be confined and exhibited in a mass like other bodies, they can be collected only through the intervention of other substances. Their title to be considered material is therefore questionable, and the effects produced by them have accordingly been attributed to certain motions or affections of common matter. It must be admitted, however, that they appear to be subject to the same powers that act on matter in general, and that some of the laws which have been determined concerning them are exactly such as might have been anticipated on the supposition of their materiality. It hence follows that we need only regard them as subtile species of matter, in order that the phenomena to which they give rise may be explained in the language, and according to the principles, which are applied to material substances in general.

From this it is apparent that the author did not feel quite sure of his ground although Rumford's experiments in 1798 had shown that heat could be generated without limit by friction alone; indeed the question was not determined until the experimental investigations of Joule, published 1843-9, established the doctrine of the conservation of energy, that heat and work are mutually and quantitatively interconvertible.

Thus, up to nearly the close of the 18th century chemistry had not become a science. No descriptions had yet been given which correlated change of properties with change of composition in such a way as to indicate new lines of investigation. Indeed the conception of chemical composition, as we now understand it, had not taken form, because the phenomena—and in particular, the change of weight—accompanying the transformation of one substance into another had not been accurately observed. From this period date the use of the balance, perhaps the most characteristic single tool of the scientific chemist, and the quantitative analysis of chemical changes; and with this advance chemistry begins to be a science, with a growing body of definite principles.

[4] "Manual of Chemistry on the Basis of Dr. Turner's Elements of Chemistry," by John Johnston (1806-79) Professor of Natural Science in the Wesleyan University; new edition, Philadelphia, 1848; p. xiii.

In rendering chemistry a science many men bore a part, but the outstanding figure is Lavoisier, born in 1743, beheaded in 1794 because "the Republic has no need of scientists," a view which, though still widely held implicitly, is not now carried to its logical conclusion in the same way as it was then. Lavoisier's "Traité élémentaire de chimie," published in 1789, is a systematic treatise which transformed the subject. He gave a definite meaning to the expression, "chemical composition"; and recognized that the quantity of matter is the same at the end as at the beginning of every operation. He stated that the object of chemistry is "to decompose the different natural bodies, and . . . . . to examine separately the different substances which enter into their combination. We cannot be certain that what we think today to be simple is indeed simple; all we may say is, that such or such a substance is the actual term whereat chemical analysis has arrived, and that with our present knowledge we are unable to subdivide further." This quotation shows that Lavoisier had a much better philosophic attitude towards the whole matter than have had many of the chemists since his time; indeed until recently chemists were so much occupied in accumulating observations that they were prone to neglect the philosophy by means of which alone these multitudinous observations can be correlated.

Lavoisier gave a table of elements, containing thirty-three names, of which twenty-three are still regarded as elements—the definition of a chemical element being that it is a substance which we have not succeeded in breaking up into anything simpler, the atoms of the several chemical elements therefore being, so to speak, the small pieces of tile of different kinds out of which are built up all of the numberless patterns or mosaics which we see about us as diverse kinds of matter. Of the others, five—lime, magnesia, baryta, alumina, silica—are oxides which, with the experimental means then available to Lavoisier, could not be decomposed. These twenty-three elements, the number known at the end of the eighteenth century, comprise the following: carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur; antimony, arsenic, bismuth, cobalt, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, platinum, silver, tin, tungsten, zinc. This list, it will be noted, includes only six non-metals, one of which—sulphur—was known to the ancients though not recognized by them as an element in the modern sense of the term. Of the seventeen metals on Lavoisier's list, seven—gold, silver, copper, iron, mercury, lead, tin—were known to the ancients, though not as elements; most of the others were isolated for the first time during the second half of the eighteenth century. Incidentally it may be mentioned, as an illustration of the slowness with which knowledge is applied, that some of these metals—notably, tungsten, molybdenum and manganese—were not used technically for

more than a hundred years after their discovery; we now value them highly, as their use enables us to achieve results of the greatest importance technically and therefore economically, results which otherwise were unattainable. It is of interest, furthermore, to note that the names of two of these elements—cobalt and nickel—derive from words meaning "the devil," ores of copper admixed with these metals being then considered useless; indeed we have only learned to make use of such ores comparatively recently. Nickel has been produced on a large scale for a short time, and no large use has yet been made of cobalt, although it is comparatively plentiful.

By the year 1800, twenty-seven chemical elements had been recognized, the four added since Lavoisier being uranium, titanium, chromium and tellurium; thirty years later, in 1830, this number had been doubled. The discovery of many of these elements (for instance, the metals associated with platinum—palladium, rhodium, iridium, osmium) was brought about by the application of more and more careful analytical methods, in the hands of men such as Wollaston and Berzelius—the latter alone adding five to the list. The isolation of others, notably the alkali and alkaline earth metals, (potassium, sodium, calcium, strontium, barium) by Davy in 1807, was achieved by a new and powerful method of analysis, namely, the application of the electric current to the breaking up of substances. Davy, after proving definitely by this means that water is composed solely of hydrogen and oxygen, established the fact, surmised by Lavoisier, that the alkalis are oxides of metals; therefore that oxygen, the acid producer as it had been named (erroneously as we now know), is a constituent of the alkalies. He was, however, puzzled by ammonia and in particular by the ammonium radicle or grouping[6] which in its salts resembles so closely the alkali metals; and this puzzle was not solved until about 1840, by which time the idea of the existence of similar compound radicles in organic chemistry was beginning to find general acceptance.

From this period dates the usefulness of the atomic theory, first clearly enunciated by John Dalton in his "New System of Chemical Philosophy" published in 1808. The speculation that matter is ultimately composed of discrete particles, or atoms, had been common in philosophical writings; but it had led to no real progress of knowledge until Dalton showed how the assumption that each element is made up of atoms serves to correlate experimental observations and to suggest new inquiries. On this basis, the myriad substances we see about us are all made up of combinations of a small integral number of atoms of the several elements present, the atoms of each element having characteristic properties, and in particular a characteristic weight. Chemical combination of one element with another is the union of an

[6]See *infra*.

atom of one element with an atom, or a small number of atoms, of the other; this number, in compounds of two elements, seldom exceeds four and is always less than eight, and it is in no wise arbitrary but in accordance with what is now termed the relative valence of the two elements. As a simple case, in the ordinary combustion of carbon (coal) one carbon atom unites with two oxygen atoms, resulting in the formation of carbonic acid gas; or, as the chemist writes it in his shorthand, $C + O_2 = CO_2$. In more complicated structures, the number of elements present may be greater than two, but is seldom greater than five; the total number of atoms making up the structure characteristic of the substance is in some cases large, but in all cases it can be pictured as made up of a number of groupings, each composed of two elements. As a simple familiar instance, limestone ($CaCO_3$) is made up of equivalent amounts of lime (CaO) and carbonic acid (CO_2), and is decomposed into these two proximate constituents in the operation of lime-burning, thus:

$CaCO_3$	$(CaO.CO_2)$	$=$	CaO	$+$	CO_2 .
calcium	carbonate		calcium oxide		carbon dioxide

Furthermore the lime, when used as mortar, is slowly reconverted into the carbonate by the action of the carbonic acid always present in the atmosphere. In many chemical processes we are dealing with an exchange of partners, the substances A B and C D becoming A D and B C; for example, hydrochloric (muriatic) acid added to a solution of silver nitrate (lunar caustic) yields nitric acid and silver chloride, the latter appearing as an insoluble white curdy substance; or in symbols, $HCl + AgNO_3 = HNO_3 + AgCl$. This illustrates the fact that the apparent affinity of one kind of atom for another is not the same under all circumstances, and that consequently a firm and long-standing union of two atoms may be broken up by the entrance of a third under appropriate conditions.

The atomic theory was a very great step in advance, establishing, as it did, the laws and processes of chemistry on a quantitative basis. Progress since Dalton's time has only served to confirm the essential correctness of the atomic theory; indeed there is now no longer need to call it a theory, for the reality of atoms is no more open to question than that of any other fact of physical science. The atoms are infinitesimally small, so small that, if a drop of water were magnified to the size of the earth, the constituent atoms would be about the size of footballs. Perhaps a more striking illustration is that, if the particles in a cubic inch of air were magnified until they would just pass through a very fine sieve (100 meshes to the inch), this fine sand of particles would suffice to cover a highway extending from New York to San Francisco, and one mile wide, with a layer about two feet deep.

We cannot see the actual atoms, it is true, but we can weigh them and measure them and study their characteristics; the same holds true for electricity, which, it may be remarked, is, according to modern views, also made up of units, named electrons, which bear an extraordinarily intimate relation to the structure of the atom itself.

In 1830, as noted above, about fifty-five chemical elements had been recognized, and these include all—with one notable exception, argon, to which we shall refer later—which have yet been found in appreciable quantities in the surface crust of the earth. Since that time the number of recognized elements has been increased by about thirty, most of which, however, are so very rare that only a few grams of them have ever been isolated—in other words, most of them are chemical curiosities kept in small tubes in museums. Indeed the recognition and isolation of the majority of these elements has been possible only through the discovery, about 1860, of the possibility of spectrum analysis. This elegant method depends upon the fact that each chemical element, whether in combination or free, gives, when viewed under appropriate conditions, a so-called spectrum made up of a series of bright lines, the positions, or colors, of which are absolutely characteristic. This method of identification is so sensitive that an element can be recognized even when it is present only in very small amount—an amount of the order of one-millionth of a gram; it therefore enables one to learn how to segregate or concentrate an element originally present in such small quantities that no ordinary chemical test would then suffice to detect it. Likewise, by observation and measurement of the spectra of the sun and stars, it has been definitely determined that the elements present in their upper layers are identical with those which make up the crust of the earth and are already familiar to us, with one or two possible exceptions.

In 1868 Lockyer, while examining the solar spectrum, observed a bright line which did not correspond to any element then known, and attributed it to a hypothetical element helium. This element was not recognized on the earth for about thirty years, although Hillebrand had in the meantime, while examining the mineral uraninite, had some in his hands, but, by reason of its inertness, considered it to be merely nitrogen. It was identified by Rayleigh and Ramsay in the course of their investigation of the inert gases of the atmosphere, an investigation which arose out of the observation—originally made, in a sense, by Cavendish, a century earlier—that there is a fractional difference in density between nitrogen prepared chemically and that obtained from purified air by removal of the oxygen. This investigation resulted in the discovery of a family of five new inert gaseous elements, all of which are present in the atmosphere, argon to the extent of about one percent. by volume, helium and the others in the proportion of a few

parts per million. Argon, therefore, although all around us in enormous quantities—within a house 33 x 33 x 33 feet there is about a ton of air and consequently some forty pounds or 10,000 litres (400 cubic feet) of argon—was not recognized, by reason of its inertness; for neither it, nor any of the argon group, has hitherto been made to enter into chemical combination. But this very inertness is now being taken advantage of; in the case of argon, as a filling for electric light bulbs; in the case of helium, as a non-inflammable filling for balloons, a matter which, during the war, was considered so important that large quantities of it were finally separated from natural gas in Texas, after many difficulties and at very large expense. Incidentally, this is an excellent illustration of the results which may follow from scientific work carried on merely to learn about things, and not with any idea of discovering something of particular use; for the possibility of producing helium on a large scale is a direct outcome of careful observations of the spectrum of various samples of natural gas.

But the greatest interest in helium, from a scientific point of view at least, is in quite another direction, namely, its intimate connection with the phenomenon of radio-activity, or better, with the disintegration of the so-called radio-elements. These radio-elements, the best known of which is radium, first discovered in 1898, differ from the other chemical elements in one respect, but that one very significant, in that they are disintegrating before our eyes. This disintegration, which proceeds at a rate unaffected by any change of temperature or by anything tried hitherto, is accompanied by a continuous emission of energy—a million times greater than is liberated in any change of matter previously known—largely in the form of material particles shot out with great velocity. This energy is so great that one can indeed count the number of particles shot out by observing the flash produced by the bombardment of a suitable screen, as in the spinthariscope, or the luminous watch dial in which the light is the aggregate of the flashes produced by a quantity of radium which weighs only a millionth of a gram. This phenomenon enables us to detect the presence of a small number of *atoms* of a radio-element; whereas the smallest number of atoms of an element which it has been possible to detect by means of the spectroscope or by the most delicate methods of chemical analysis is at least 10^{12}, a number the magnitude of which will be more obvious from the statement that it is several hundred times the total present human population of the world. It is now definitely established that these material particles are helium atoms, and that this disintegration of the radio-elements is an actual transmutation, a transmutation, however, beyond our present powers to control. If we should ever learn to control this atomic disintegration, it would effect a much greater revolution than was caused by the utilization of coal for power; for in that

case the energy derivable from the atomic disintegration of a shovelful of material would be as great as that now derivable from a thousand tons of coal—in other words we would then be possessed of limitless stores of energy. This has not been done yet, it may not be achieved for a long time, it may not be possible; but he would be a rash man who would deny its possibility. The phenomenon of radio-activity is a very striking illustration of the way in which a new method, a new tool of research, may open up a field which otherwise we would not even sense—nay, hardly be bold enough to imagine; and there is absolutely no reason for believing that other equally novel and unsuspected discoveries will not be made in the future.

From the fact that the material particles shot out by a disintegrating radio-element are helium atoms, it would appear that the helium atom is one of the kinds of brick which go to make up the more complex type of structure of the atoms of the heavier elements. Now the two simplest and lightest atoms known are the hydrogen atom and the helium atom; and there is ground for believing that the hydrogen atom also is one of the bricks of the atom-builder. Indeed recent experiments of Rutherford (1920) indicate that he has succeeded, by bombarding nitrogen atoms with helium atoms, in dislodging hydrogen atoms from somewhere—presumably from the nitrogen atom. If this is confirmed, we shall have to introduce an interpretative reservation into the present definition of an element, according to which a chemical element is a substance not yet resolved into something simpler. This however, is hardly part of the *history* of chemistry; though, one may ask, what is the use of history, beyond being a sort of literary exercise, if it does not enable us to make general predictions as to what is going to happen, for then only will it be a science.

The deduction from experimental evidence that the hydrogen and the helium atom are two of the building bricks brings us back to a very old idea, to the idea that matter as we see it or—one would now say preferably,—the chemical elements are made up of one, two, or at most a few, kinds of primordial stuff. The relative weight of the atoms of the several elements can be determined by simple experiments; these atomic weights were usually referred to hydrogen as unity, hydrogen being the lightest known element, but for practical reasons are now referred to oxygen = 16.00, there being only a fractional difference between these two standards of reference. It was early observed that a much larger proportion of these atomic weights approximate to whole numbers than can be accounted for on the theory of chances. From this it was inferred that the hydrogen atom was this ultimate unit; but there were a number of well established marked exceptions[7] which would not be explained away and so tended to discredit the doctrine. Nevertheless this hypothesis, often called Prout's hypothesis, continued

to be a useful one, as it was the occasion of much of the best work on atomic weights; and in spite of the exceptions, it persisted as an aspiration which was rewarded in time by the discovery of the periodic law of the chemical elements, established by the writings of Mendelejeff.

According to this great generalization "The properties of the elements, and, therefore, the properties of the simple, and of the compound bodies formed from them, are in periodic dependence on their atomic weights." In other words, if the elements are arranged in order of increasing atomic weight, we find that like properties recur regularly, and that by this means like elements are brought together into natural groups, e. g. the alkali metals, the halogens, the inert gases. This periodic classification had a profound effect in leading us toward the correct value of atomic weight of many elements; and in enabling predictions to be made as to the existence and properties of undiscovered elements, predictions which were completely verified in three cases by the subsequent discovery and investigation of the properties and relations of scandium, gallium and germanium. But to record all the consequences of this periodic law would be to recount the achievements in inorganic chemistry in the fifty years elapsed since its discovery; suffice it to say that it forced the chemist to cease thinking about the elements as unrelated entities and instead, to consider them as members of a family or, at the least, as members of a series of related families.

Time has only served to corroborate the essential correctness and usefulness of the periodic classification of the chemical elements; and no evidence has been more conclusive than that derived, within the last few years, from investigations of X-rays and of radio-activity. This work has led to the conception of a characteristic atomic number which changes by unity in passing from one element to its neighbor in the periodic system. It appears indeed that this atomic number is really more fundamental than the atomic weight, that all the properties of an atom, save mass and radio-activity, depend upon the atomic number, which is the number of negative electrons (i. e. atoms of electricity) surrounding the positive nucleus at which the mass of the atom is assumed to be concentrated; or rather, that the distribution of the negative electrons on which the ordinary physical and chemical properties depend is a function, and a periodic function, of the units of electric charge on the nucleus, and hence of the atomic number. It is believed that the lightest known element hydrogen has an atomic number of 1, helium of 2, lithium of 3, and so on up to thorium and uranium, the

[7]These are now showing signs of yielding, in that the elements in question seem to be mixtures of so-called isotopes which have identical chemical properties, and so can not be separated by chemical means, but differ slightly in characteristic weight.

heaviest known elements, with atomic numbers of 91 and 92 respectively. If these views should be confirmed—and their success in correlating diverse phenomena makes it certain that the picture they present is one aspect of reality—we shall have nearly returned to the hypothesis of a primordial stuff; for present evidence indicates that the positive nuclei of hydrogen and helium and the negative electron are amongst the units from which the atoms of the elements are built. But this again is history in the making.

From the considerations just outlined it appears that all of the chemical elements as we know them are of a similar order of complexity, since they belong to a series of families; and consequently that any means which will decompose one element will also decompose others. Moreover, the sequence of atomic numbers indicates that only five elements are missing in the series up to uranium, the heaviest element now known and the parent of one of the two series of radio-active elements. Whether elements heavier than uranium exist is open to question; if they do exist, they would presumably be radio-active, and with a shorter life than uranium. The most common elements in and about the surface layers of the earth are in general elements of smaller atomic number, as is shown by an estimate of the percentage of the several elements which go to make up the earth's "crust," defined for this purpose as a layer ten miles in thickness.

It appears that two elements, oxygen and silicon—the latter wholly in primary combination with the former, the remainder of the oxygen being combined with the other elements—together constitute three-quarters of the earth's crust; and that the eight most abundant elements make up nearly 99 per cent. of the whole.

It is also noteworthy that, of the metals in daily and common use, only aluminum, iron, manganese, chromium, vanadium, and nickel, appear among those elements that are present in the rocks of the crust in sufficient amount to be commonly determinable by the usual processes of analysis. Such common and "every-day" metals as copper, zinc, lead, tin, mercury, silver, gold, and platinum, antimony, arsenic, and bismuth—metals that are of the utmost importance to our civilization and our daily needs—all these are to be found in igneous rocks, if at all, only in scarcely detectable amounts. Though they are ultimately derived from the igneous rocks, they are made available for our use only by processes of concentration into so-called ore bodies.[8]

Up to the present, then, the number of known chemical elements is, excluding the isotopic radio-elements, about eighty. That is, chemists, in spite of laborious and prolonged efforts, analyzing all manner of material from all quarters of the globe—and even from the heavens in the form of meteorites—have been able to resolve their multitudinous diversity into combinations and permutations of some eighty substances; and these hitherto irreducible minima—the so-called chemical

[8]H. S. Washington, J. Franklin Institute, Dec., 1920, p. 778.

elements—are members of a family, or of a group of families, and so represent the same stage of simplicity or complexity of structure. Knowledge of the structure of the atom is extending rapidly, but it would lead too far afield to go into this absorbing question here.

Development of Ideas Respecting Chemical Combination, Particularly in Organic Chemistry

The chemical elements are not all of the same degree of importance to us, although there are not very many which we could well do without; but there are four, in a sense, of supreme importance, as they are the main constituents of all living matter. These four elements are carbon, hydrogen, oxygen, nitrogen, with which are associated relatively small, but absolutely indispensable, proportions of other elements. For a long time it was thought that the substances which make up living matter—the so-called organic compounds—were associated with some sort of vital force, and so were to be placed in another category from mineral substances—the inorganic compounds. But this distinction was broken down, for the first time, nearly one hundred years ago; it remains now only in the names organic and inorganic chemistry, the term organic chemistry now connoting merely the chemistry of carbon compounds, from whatever source derived.

So long as the idea persisted that the behavior of organic substances is determined more or less by a mysterious vital force, progress, it is obvious, could hardly be rapid; and indeed the rise of organic chemistry as a science may be said to date from Wöhler's discovery, in 1828, that urea—a typical product of the animal organism—could be made from materials classed as inorganic compounds. Under certain conditions, the molecule[9] of ammonium cyanate, which is a compound of the ammonium radicle (NH_4) with the cyanate radicle (CNO), undergoes a rearrangement, a change of grouping, yielding urea; or as we would now symbolise it

$$\underset{\text{ammonium cyanate}}{NH_4 \cdot OCN} \longrightarrow \underset{\text{urea}}{OC\begin{matrix}NH_2\\NH_2\end{matrix}}$$

Here we have, therefore, two different substances composed of the same atoms, and convertible one into another by appropriate treatment; this instance illustrates the fact that the properties of a compound de-

[9]The molecule may be defined, for our present purpose, as the smallest portion of a compound which can be conceived to exist alone; for subdivision if it were carried further, would break up the compound into its constituent parts. The radicle is a grouping of elements, which reacts as a unit and is like a chemical element in many respects, with the outstanding difference that the radicle can, by appropriate treatment, be decomposed into its elements or altered.

pend, not only upon the kinds of atoms and number of each present, but also upon the *arrangement* of these atoms within the molecule. In other words, the behavior of a substance is dependent upon its constitution, just as the behavior of an animal is dependent upon its constitution. But this is to anticipate by some thirty years; for at that time chemists were still a long way from a clear understanding of the matter. The primary reason was a confusion between the atomic weight and the combining weight to be assigned to an element; this confusion resulted in a lack of consistency in assigning formulae to substances—for instance water was then frequently written HO—a circumstance which in turn, so to speak, hid the simple relations of the several compounds and, indeed, makes it hard for us now to follow much of the writing on chemistry at that time. But it would lead too far into a field of interest only to the chemist, to recount the various steps in the slow advance towards an attainment of consistent ideas of chemical combination and constitution. We can only mention some of the outstanding figures in this advance: Wöhler and Liebig, with their discovery (1832) of the radicle benzoyl; Dumas, with his older type theory (1839), Gerhardt and Williamson with modified theories of types of formulation of organic compounds.

Liebig's name cannot however be passed over without mention of the enormous influence which he and his teaching had upon the development of the subject. Shortly after becoming professor at Giessen in 1824 he instituted systematic laboratory instruction in chemistry, and Giessen soon became the most famous chemical school in the world, attracting many who were subsequently themselves to become leaders in further development. Still more important was Liebig's pioneer work on the chemistry of the processes of life, both animal and vegetable, work which makes him the real founder of two branches of the subject—biochemistry and the chemistry of agriculture; the development of these two branches is being attended with incalculable benefits to human welfare.

From about 1830 onwards, interest in chemistry enhanced steadily, the number of competent workers grew rapidly, and there was a constantly increasing body of facts of observation; but these various observations and the deductions from them awaited reconciliation and interpretation which came only when the proper theory was developed. This did not happen until 1860 when, at a conference which had been called in the hope of bringing about some more general understanding of the questions at issue, Carrizzaro brought to the attention of the chemical world the hypothesis of Avogadro, showed how on this basis the apparent anomalies disappear, and so clarified the whole situation. Indeed it may be said that modern chemistry dates from 1860, with the enunciation of clear and consistent views with respect to chemical com-

bination, as a direct consequence of grasping the real significance of Avogadro's hypothesis.

From the gas-laws of Boyle and Gay-Lussac—namely, that equal changes in pressure and in temperature occasion equal changes in equal volumes of gases—and from Gay-Lussac's discovery (1809), that two gases reacting with one another do so in simple proportions by volume and that the volume of the product, when gaseous, also bears a simple relation to that of the factors,—reasoning from these Avogadro about 1811 was led to the hypothesis: Under the same conditions of temperature and pressure, equal volumes of gases contain equal numbers of molecules. The molecule is the smallest particle of a substance obtainable by *mechanical* subdivision; the atom can be obtained only by *chemical* subdivision of the molecule of which it constitutes a part, and is therefore a particle usually incapable of persisting alone but in most cases existing only in combination with other atoms. This combination may be between like atoms, in which case the molecule so formed is that of the element itself, or between unlike atoms, constituting the molecule of a compound. In either case the same principle holds; with the obvious deduction, as Avogadro showed, that the relative weight of two species of gaseous molecules is measured by the ratio of the weights of equal volumes, under the same conditions of temperature and pressure,—i. e. of the densities—of the two gases. A molecule of the elements which are gaseous under ordinary conditions is made up of two atoms, with exception of the family of rare inert gases which are monoatomic; that of other elements,—for example, sulphur—may contain six or more; in all cases there is, as we now know, a progressive dissociation of the molecules with increasing temperature and diminishing pressure, so that at the highest temperatures and lowest pressures a large proportion of the molecules are in effect broken up into monoatomic particles.

With the acceptance of Avogadro's hypothesis, the chemist had at last a definite criterion for deciding when he was dealing with really comparable quantities of elements or of compounds; he was enabled to fix the atomic weight definitely, and hence to deduce the correct empirical formula of his compounds. When this was done, many things became clear. For instance, the full significance of the idea underlying the theories of radicles and types, which had been developing for the previous twenty or thirty years, became apparent; and this, in turn, led to the conception of valence, according to which the atom of each element has a maximum saturation capacity with respect to other atoms.

Certain groupings of atoms are so relatively stable that they remain in combination although chemical change is effected in the molecule as a whole; such groupings, known as radicles, react commonly as units and are therefore in many respects analogous to chemical elements, the

chief differences being that the radicle cannot commonly be isolated as such and that it can, of course, be decomposed into its constituent elements. The earliest clear example is the ammonium radicle (NH_4) which forms a whole series of salts differing no more from the corresponding salts of potassium (K) and sodium (Na) than these differ from one another; in other words, NH_4 can, in principle, replace K or Na in a whole series of compounds each of which closely resembles its analogue. Likewise we have a whole series of organic radicles, ranging from the simplest—methyl (CH_3), ethyl (C_2H_5 or $CH_3.CH_2$)—up to quite complex groupings,—such as stearyl ($C_{17}H_{35}CO$ or $CH_3.(CH_2)_{16}CO$) but all ideally reducible to a small number of types. For instance, consider the following series of compounds, with the corresponding analogues in which hydrogen (H) is substituted for methyl (CH_3):

$CH_3 \cdot H$ methane, the main constituent of natural gas	$H \cdot H$ hydrogen gas
$CH_3 \cdot OH$ methyl alcohol	$H \cdot OH$ water
$CH_3 \cdot Cl$ methyl chloride	$H \cdot Cl$ hydrochloric acid
$CH_3 \cdot CHO$ acetaldehyde	$H \cdot CHO$ formaldehyde (formalin)
$CH_3 \cdot COOH$ acetic acid (vinegar)	$H \cdot COOH$ formic acid
$(CH_3)_2O$ methyl ether	H_2O water
$(CH_3)_2S$ methyl sulphide	H_2S hydrogen sulphide

This list could be extended indefinitely, in either direction; for a whole series of other radicles can be regarded as derived from methyl by successive substitution in place of one or more of its H atoms, of CH_3 groups or chlorine atoms or indeed of any other atom or radicle which exhibits the appropriate affinity relations. For instance, we have:

$CH_2 \cdot H$	$CH_2 \cdot CH_3$	$CH_2 \cdot CH_2 \cdot CH_3$	$CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_3$
CH_3	C_2H_5	C_3H_7	C_4H_9
methyl	ethyl	propyl	butyl

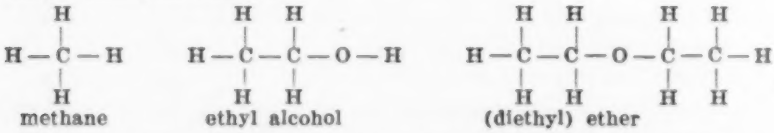
and so on, in homologous series, as it is termed; further C_2H_4Cl, chlorethyl as in $(C_2H_4Cl)_2S$, dichlorethylsulphide (mustard gas); CCl_3, trichloromethyl, as in $CCl_3 \cdot CHO$, trichloraldehyde (chloral), and so on.

With the recognition of the relationships just outlined, of the existence of radicles related to one another in a simple manner and of the fact that the multifarious compounds are formed by the possible combinations of the several radicles and elements, it became possible to organize a consistent nomenclature. The advantage of this is obvious; for if to each chemical compound had been assigned an arbitrary name (as has been the case in naming minerals) it would have been possible to read chemical literature only by memorizing a list numbered now in hundreds of thousands—a task which would have been harder than learning the Chinese characters, and would have resulted in a similar retardation of progress. For certain common substances or common

groupings specific names are retained, but in general the name is designed to exhibit the constitution—and therefore the general properties and behavior—of the substance with the least possible memory work; and the chemist gets from these names, in some cases apparently very complicated—e. g. phenyl-dimethyl-isopyrazolone (antipyrin), dimethyl-methane-diethyl-sulphone (sulphonal)—much more information about the substance than the layman gathers from the term "third assistant secretary to the fourth assistant postmaster-general" with respect to the real function of that personage. As simple examples of systematic naming, consider the substances obtainable by chlorinating methane:

CH_4	CH_3Cl	CH_2Cl_2	$CHCl_3$	CCl_4
methane	chloromethane (methyl chloride)	dichloromethane	trichloromethane (chloroform)	tetrachloromethane (carbon tetrachloride)

Closely allied to the doctrine of radicles and types is the doctrine of valency, according to which each element has a maximum saturation capacity with respect to other elements. This doctrine developed about the same time, though in somewhat more rigid form than would now be generally accepted. Accordingly, to carbon was assigned the valence 4, to oxygen 2, to hydrogen and chlorine 1, and so on; and it was but a short transition to picture the valence numbers as the number of linkings or bonds with which one atom may hold others, and from this to the writing of graphic or structural formulæ. The graphic formula enabled the organic chemist to represent still more satisfactorily the structure of his substances, and has been an indispensable tool in the subsequent great development of organic chemistry; the following simple examples will suffice:

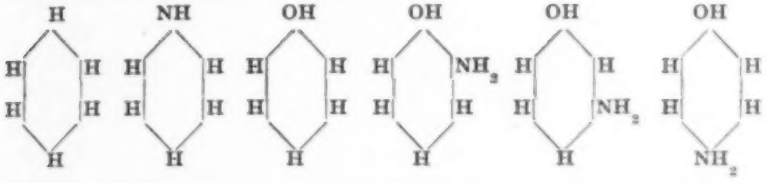


In 1861 appeared the first portion of Kékulé's great text-book which emphasized and illustrated the new views with hundreds of examples. The foundations of modern organic chemistry were therein laid and, what is more important for us here, the date marks the time when the great contribution of organic chemistry to the historical development of the science as a whole was fully rendered.[10]

So far we have mentioned only compounds whose structure can be represented by a straight chain of carbon atoms, and grouped under the general name of aliphatic (or fatty) compounds from the circumstance that fats belong to this category. But there is another category, the so-called aromatic compounds, the simplest, and typical member of which is benzene, which has the empirical formula C_6H_6. A satisfactory structural formula for this substance was first given, in 1865,

[10]F. J. Moore, History of Chemistry, p. 173.

by Kékulé who assumed that the six carbon atoms are arranged in a ring, a single hydrogen being attached to each; and all the subsequent work on aromatic compounds has only served to confirm the usefulness of this hypothesis. One instance only can be mentioned here, namely, that whereas there is only one mono-substitution product, (i. e. where one atom of hydrogen is replaced by a different atom or grouping, as in phenol) there are three disubstitution products (designated as ortho, meta, para) which differ by reason of the different relative position of the two substituting groups. This will be evident from the structural formulae, as now written:



The long controversies which ended about 1860 in the triumph of Avogadro's hypothesis and the vindication of the atomic theory had been fought out in the organic field, and had culminated in the establishment of the valence theory as the guiding principle in that branch of the science. This gave, perhaps, to organic chemistry a somewhat exaggerated importance —at any rate, the idea that chemical compounds could be visualized as groups of real atoms united by real bonds exerted a remarkable fascination, and young chemists in great numbers began to devote themselves to synthetic studies, attempting on the one hand to prepare from the elements the most complex products of nature, and on the other to make the greatest variety of new combinations in order to find the utmost limits of chemical affinity and molecular stability. The rise of the coal-tar industry and the possibility of preparing from this source so many compounds of practical utility was partly cause and partly effect of this great movement which is going on uninterruptedly at the present day.

If, however, we ask what direct contribution *to the science as a whole* has been made by organic chemistry since 1860 we can hardly give it so high a place. We must rather confess that this branch of the science has lived largely for itself and while it has, during that time, developed a real history of its own which is of fascinating interest to the specialist, its great historical service to chemistry culminated in the work of Williamson, Gerhardt and Kékulé.[11]

(To be concluded)

[11]F. J. Moore, History of Chemistry, p. 212; italics mine.

HERMANN VON HELMHOLTZ[1]

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THE history of science concerns itself with the historical and logical sequence of scientific concepts. The process of development by which man arrives at fundamental laws of the universe in which we live is a vital study, having great possibilities for furthering the advance of science. Studies in this field have shown that the part of particular individuals, even men of great genius, is much less than is commonly supposed. Advance in science rests upon the work of many individuals whose observations and reflections cover rather long intervals of time. The genius is that fortunate individual who arrives upon the scene when the accumulation of observations enables the formulation of some general law for whose reception and acceptance the way has been prepared. The genius "reaps where others have sown"; the genius is great, as Newton intimated, because he stands upon the shoulders of giants.

Obviously only few men can be successful in attaching their names to fundamental laws. Prominent in this group is Hermann von Helmholtz, who in 1847 at the age of twenty-six, gave a complete statement of the law of the conservation of energy. Good fortune came his way in this law of energy and more than once again, but it must be said that Helmholtz met good fortune more than half-way, and entertained her so royally that no one could dispute his right to the visitation.

Helmholtz was favored, also, in living to see the law of the conservation of energy accepted as a truism, to see this law made the basis of the researches of hundreds of able scientists, and in being able himself to devote nearly half-a-century of vigorous intellectual activity to problems intimately connected with his first success. Towards the very end of his life in 1894, the great German was working upon the similar but more inclusive "principle of least action" which he hoped to extend mathematically so as to apply to all forces of nature.

Helmholtz applied rigorously to biological problems the methods of physical science and mathematical reasoning. His activity marks the beginning of the period in which philosophical speculation about

[1] A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

science was definitely superseded by experimental research in science, combined with mathematical treatment of the observations. The law of the conservation of energy was stated by him with a wealth of illustrations from mechanics, electricity, heat and biology, but it also included a mathematical formulation and discussion of the problem. In the study of physiological optics and of light, in the study of sound and harmony and the ear, in the study of the psychology of the senses, in the study of vortex motions, in the study of electrical phenomena and of physics generally, Helmholtz constantly reinforced experimental work with rigorous mathematical demonstration. Were one to attempt to characterize in a few words his extraordinary range of researches, one would say that Helmholtz brought biological and physical problems under the dominion of mathematical formulas and methods.

The rôle of the mathematical formulation and treatment of physical problems can not be overestimated. Kelvin, the intimate friend and active co-worker in science with Helmholtz, has stated: "All great scientific discoveries are but the rewards of patient, painstaking sifting of numerical data." With these data the scientist starts, making fundamental assumptions in the mathematical formulation of the problem. The successful formulation explains on the basis of the fundamental assumptions the observed facts; further than this, the procedure places the observed facts in harmony with other apparently widely-diverse phenomena, showing the harmony of natural forces and the reign of law in nature. But more than this the mathematical formulation suggests new facts of observation, and permits the prediction of observations which had previously escaped the observer. This is the peculiar merit, for example, of the Einstein theory, that it explains the facts of the Newtonian universe, explains certain facts which were in conflict with the Newtonian theory and enables the theorist to predict other natural effects not consonant with the Newtonian theory and hitherto unobserved. This type of mathematical ability Helmholtz had in a surprising degree, and it made possible his contributions to the advancement of science.

In a centennial recognition of a life of such great significance for mankind, the purpose is both historical and inspirational. What is the historical setting of the contributions of Helmholtz to civilization? What were the circumstances of birth and training, of academic position and environment, which made possible the wonderful productivity in apparently diverse fields of science? What can we do to foster the production of such men and to encourage this type of devotion to pure science? This brief survey of the life and activity of Helmholtz is prepared from the point of view of these questions.

Hermann von Helmholtz was born in Potsdam, August 31, 1821. His father was a teacher of philology and philosophy in the Potsdam

gymnasium, while his mother was a lineal descendant of William Penn. Despite a certain frailty of body his preparatory work included not only the traditional classical course with Latin, Greek and Hebrew, but also English and Italian, privately, with a beginning of Arabic, together with serious training in music. Even in the schoolroom he found further time for experimental work in physics and science. At the age of sixteen, although then desiring to devote himself to physics, he took an examination for a scholarship in the Royal Frederick William Institute of Medicine and Surgery, since the financial status of his family made desirable the election of the surer means of livelihood in medicine. One year later, Helmholtz entered upon the strenuous five year course of the institute. Here he completed the regular work, and studied, while acting as librarian, the works of Euler, Daniel Bernoulli, d'Alembert and La Grange. His thesis, "The Structure of the Nervous System in Invertebrates," contained the announcement that the nerve-fibers originate in the ganglion cells found by Von Ehrenberg in 1833; this discovery has been regarded by some physiologists as the histological basis of nervous physiology and histology.

For one year Helmholtz acted as house surgeon at the Charité in Berlin and then for five years at Potsdam as army surgeon as required of graduates of the institute. During these six years, he maintained active scholarly relationships with his teacher Müller, and with his intimate school friends, Brücke and du Bois Reymond, physiologists of later repute.

At this time the vitalistic theory was still dominant in physiology. Müller proposed the problem as to the nature of the vital force, whether self-engendered or similar to those of the inorganic world. This study of "vital forces" and the formulation given to the problem by Liebig, the chemist, stimulated the young student to several studies concerned with animal heat and with vitalistic problems. During these six years Helmholtz acquired further familiarity with mathematical physics and chemistry, made necessary by the problems he was considering. It was in this period, in 1845, that the Physical Society was founded by du Bois Reymond, Brücke, Karsten, Knoblauch, Beetz and Heintz, and Helmholtz became one of the most active members with many contributions, published in the *Fortschritte der Physik*.

On July 23, 1847, Helmholtz read before the Physical Society his paper, "Die Erhaltung der Kraft." This paper was offered to Poggendorff's *Annalen*, but rejected by Gustav Magnus, the physicist, since he regarded experimental and mathematical physics as separate departments. In fact, Magnus warned Helmholtz "against undue partiality for mathematics, and the attempt to bring remote provinces of physics together by its means."

Despite the peculiar objection of Magnus, unfortunately shared

by many physicists of that day, the article was published and received the enthusiastic support of a chosen few who recognized the relationship to the work of earlier mathematical physicists.

In 1848, Helmholtz received the appointment as lecturer in anatomy at the Academy of Art and assistant in the Anatomical Museum of Berlin, in recognition of his researches, and a year later was called to Königsberg as professor of physiology.

In 1885, Helmholtz became professor of anatomy and physiology at Bonn, where he remained but three years, being called in 1858 to Heidelberg as professor of physiology. In 1871, at the age of fifty, he received the call as professor of physics to Berlin, having at that time incidentally made contributions to physics comparable in both range and worth with those made by any other physicist of the same period. In 1888, Helmholtz was relieved of teaching to devote himself entirely to the Physico-technical Institute of Berlin of which he became the first president. In this office the great scholar continued until his death in 1894.

The first fruits of his lectures at Königsberg on the physiology of the sense organs was the invention, late in 1850, of the opthalmoscope, an instrument which renders it possible to examine the retina of the living eye. Helmholtz says:

> While preparing my lectures I hit upon the invention of the opthalmoscope, and then on the method of measuring the velocity of nervous impulses. The opthalmoscope became the most popular of my scientific achievements, but I have already pointed out to the oculists that good fortune had more to do with it than merit. I had to explain the theory of the emission of reflected light from the eye, as discovered by Brücke, to my students. Brücke himself was but a hair's breadth off the discovery of the opthalmoscope. He had only neglected to ask himself what optical image was formed by the rays reflected from the luminous eye. For his purpose it was not necessary to put this question. Had it occurred to him, he was just the man to answer it as quickly as I, and to invent the opthalmoscope. I was turning the problem over and over, and pondering the simplest way of making it clear to my audience, when I came on the further issue.

The opthalmoscope established the position of Helmholtz in the scientific world. More than that, opthalmic medicine had a new birth with this instrument and with the opthalmometer which Helmholtz perfected for measuring the physical constants of the eye. Many students were drawn to this field, although his description of the opthalmoscope, published in 1851, was somewhat slow in general acceptance because of the mathematical and physical knowledge pre-supposed. Helmholtz himself stated:

> I attribute my subsequent success to the fact that circumstances had fortunately planted me with some knowledge of geometry and training in physics among the doctors, where physiology presented a virgin soil of the utmost fertility, while, on the other hand, I was led by my acquaintance with

the phenomena of life to problems and points of view that are beyond the scope of pure mathematics and physics.

With both the opthalmoscope and the opthalmometer, thorough familiarity with mathematical physics was absolutely essential in the theory and construction of the instruments.

His inaugural lecture "on the nature of human sense-perceptions" was delivered at Königsberg on June 28, 1852. This discussion involved, in connection with the study of sensations of sight, problems of the theory of knowledge; it also involved an exposition of the undulatory theory of sound and light, including the statement that light rays and heat rays are identical, impinging on two different kinds of nerve end organs.

For more than fifteen years, Helmholtz worked intensively on physiological optics and his "Handbuch der Physiologischen Optik" (1856-66), marks an epoch in the physiology of the eye, in the physiological-psychology of sensations and perceptions of sight, and in the physical theories of light and color. To-day the current issue of the "Handbuch" is published with four editors to present adequately the varied fields mentioned. To particularize further his numerous contributions to optics would take more time than is at my disposal. It may be of interest to the many sufferers from astigmatism to know that this condition was discovered by Helmholtz with his opthalmometer; the defect is that the cornea and crystalline lens are not accurately centered, preventing the sufferer from seeing vertical and horizontal lines with equal clearness at the same time.

The "Handbuch der Physiologischen Optik" will long remain as one of the most noteworthy contributions made to physiological psychology, not alone from the strictly physiological and the psychological sides, but quite as much because of the comprehensive grasp of geometrical and physical properties of light and lenses as related to the physiological structure of the eye and the sensations communicated to the brain.

The notion that sensations of light and color are only symbols for relations of reality, giving no knowledge of the real nature of external phenomena, was one fundamental conclusion of these researches on optics. The wide interest in this subject induced Helmholtz to investigate the subjectivity of sensation for the other senses, beginning with acoustics. In this field the physicist, Ohm, has suggested "that the ear analyses and hears the motions of the air in exact correspondence with Fourier's series." This theorem of Fourier states that any periodic function of a variable may be expressed as the sum of periodic sine functions, of x and integral multiples of x, or, in other words that any repeating wave form may be decomposed into a number of simple waves of different length, the longest of the same length as the given

wave and the others of one half, one third, one fourth, and so on, integral portions of this length. This application of a mathematical theorem to a physiological process was in such harmony with the preceding work of Helmholtz that no surprise is occasioned by his extension and development of the idea. Particularly the application of this theory to harmony was an outstanding contribution made by Helmholtz. Consonance, he taught, is produced when the ear perceives as a continuous sensation tone movements that are regularly repeated at given intervals; on the other hand, discontinuous sensation gives dissonance. Mathematically he demonstrated that vibrations in the ratio of small integers give rise to movements regularly repeated. The place of resonance and of the upper partial tones in the theory of consonance and of sound was definitely established by mathematical methods with most ingenious mechanical devices for making these upper partials evident to an observer. So far as the physiological structure of the ear is concerned, his theory was that the fibers of the basilar membrane act like the strings of a piano, and furnish the instrument of analysis into simple tones. Here, in this field the text-book which he wrote was again the result of a series of contributions to the theory of sound, based commonly upon mathematical formulation of the problems involved.

In mathematical physics proper, probably the most noteworthy contribution is that of 1857 "On the integrals of the hydrodynamic equations which express vortex-motion." The treatment both from the mathematical and the physical point of view is still fundamental in the discussion of the motions of fluids. Another paper of 1859 treats "the theory of aerial vibrations in tubes with open ends," in which from purely theoretical considerations he deduces the relations between the plane waves of the tube and hemispherical waves that spread from the tube, solving the problem of the influence of the open end upon the sound and determining the necessary lengths[2]. Kelvin elaborated the theory of vortex motion, the indestructibility of the vortex furnishing an approach to a theory of the constitution of the matter.

The electrical researches of the later years came at a period when fundamental changes in point of view were preparing. Helmholtz had accepted and furthered Maxwell's electro-magnetic theories and his gifted pupil, Hertz, achieved the experimental confirmation of the Maxwell theory, leading to the development of wireless telegraphy. Helmholtz was not only receptive to the new ideas, but active in their

[2]It is of some interest to know that Steinway worked in the laboratory of Helmholtz during the time of Helmholtz's researches on sound. One of our own Michigan professors, Watson, the astronomer, sat on the jury of award at the Paris Exposition where the Steinway piano was given first place largely because of its superiority from the scientific standpoint. (This note is supplied to the writer by Professor A. A. Stanley.)

dissemination. In his Faraday lecture of 1881, he definitely propounded the atomistic theory of electricity now commonly accepted, which is intimately connected with fundamental chemical problems. Several studies on the thermodynamics of chemical processes followed, and the Helmholtz-Gibbs equation is to-day the fundamental theorem in this field.

Helmholtz recurred so frequently in popular lectures and in scientific papers to the conservation of energy that it seems desirable to discuss the historical setting of this contribution. Particularly also, since an acrid controversy arose over the question of priority in statement. Englishmen to-day commonly credit an Englishman with the first statement, while the Germans, with better right in this case, credit a German, Robert Mayer. This arouses popular interest; many more people can comprehend the theft of an idea than can comprehend the idea. Particularly to follow the genesis of an idea requires a certain concentration which is not popular.

At the time of Helmholtz, the indestructibility of matter was accepted, apparently first started by Huygens, (1629-95). The Academy of Sciences at Paris had declined to receive any further attempts at perpetual motion since they assumed that energy could not be created. Huygens even made a general statement, in his treatise on light, that true philosophy is that "in which one conceives the cause of all natural effects as mechanical." So far as heat and energy are concerned, it is true that at this time many scientists still considered heat as a substance. However, Rumford, in 1798, showed definitely by observations on the boring of cannon that the substance theory was not tenable; Sir Humphry Davy, in 1799, clinched the argument of heat generated by friction by rubbing two pieces of ice together and generating sufficient heat to melt the ice. With Carnot, in 1824, heat was definitely recognized as a form of energy, and Clapeyron, writing in 1834 in the *Journal de l'école polytechnique* reprinted in 1843 in Poggendorff's *Annalen*, states definitely that a quantity of heat and a quantity of work are "magnitudes of like nature and that it is possible to substitute the one for the other."

The possibility of the universal application of these and other related facts to the whole field of energy was seen almost simultaneously by different observers. Robert Mayer, a German physician located in a small village, was certainly the first of this period, in 1842, to make the general statement in a paper "On the forces of inorganic nature," and he had it at first rejected by physicists of repute, and unnoticed after publication. Joule, a brewer scientist of England, in 1843 presented before the British Association a paper in which he gave the mechanical equivalent of heat, and studied relationships between electrical and chemical and mechanical effects, while in 1847, he gave the com-

plete formulation of the principle of the conservation of energy. The formulation by Helmholtz came at a more fortunate time and place, with a richer presentation involving mathematical investigation of the fundamental considerations. But the priority of Mayer can not be disputed; nor can one dispute the great value of Joule's determination of the mechanical equivalent of heat.

A general idea of such wide significance is only possible because it is, more or less, "in the air." The idea is of value because it is definitely related to the past and to the present; the great idea must be capable of appreciation by an active group of intellectual workers, and this appreciation is only possible for an idea which has had some orderly process of growth.

Helmholtz assumes that all problems of natural science can be reduced to "unchangeable, attractive and repulsive forces whose intensity depends upon the distance. The solution of this problem is the condition for complete comprehension of nature." This assumption has within ten years been definitely rejected. Notably Albert Einstein, in a paper on "Theoretische Atomistik," and Max Planck, in a paper on "Das Prinzip der Kleinsten Wirkung," reject this conception, while retaining the greater part of the theoretical achievements of Helmholtz in his conception of the conservation of energy and the principle of least action.

Helmholtz, it should be noted, resolutely set himself against any commercialism or financial exploitation of his researches. His words on this subject are worthy of serious consideration to-day in every great American university, where in some departments a tendency exists to mix devotion to science and learning with devotion to private interests. Helmholtz says: "Whoever, in the pursuit of science, seeks after immediate practical utility may generally rest assured that he will seek in vain, . . . we must rest satisfied with the consciousness that he too has contributed something to the increasing fund of knowledge on which the dominion of man over all the forces hostile to intelligence reposes."

Helmholtz was always one of the leading figures in the academic communities in which he worked. In the German universities of that day, as in the English and European Universities of to-day, the productive scholar was given the tribute of popular recognition. No administrative officers, neither presidents nor deans, nor bursars nor secretaries, served to divert student and popular attention from the men who made the university a place of learning. In fact, the attitude towards scholarship was such that political office was tendered to Helmholtz, and every recognition the state could bestow upon an individual was given him.

One concession Helmholtz made to this popular interest, which

should also be seriously considered by American scholars, particularly in our great universities. Helmholtz prepared popular expositions for general audiences of the results of his own and allied researches. These popular expositions attracted in print a great circle of readers, undoubtedly contributing to a wider appreciation and understanding of the methods and aims of science. This type of activity, so much neglected in our own universities, should be, as a university matter, a concern of the Research Club. Now it is only a matter of accident, if students of this university and citizens of this state learn what are the real contributions to human progress made within the walls of this institution. Not otherwise can a wider appreciation for true science be obtained than through the active cooperation of productive scholars.

In closing, I wish to point out how easily a man's life may be given a false interpretation by apparently competent observers. No less able a writer than W. K. Clifford states of Helmholtz that in studying the eye and ear "he found it was impossible to study the proper action . . . without studying also the nature of light and sound, which led him to the study of physics; he is now one of the greatest physicists of the century . . . . He then found it was impossible to study physics without knowing mathematics; and accordingly, he took to studying mathematics, and he is one of the most accomplished mathematicians of this century." This statement is both false and pernicious; and yet has received wide circulation and recognition. False it is because at the age of 26, and continuously for many years thereafter, Helmholtz demonstrated himself to be one of the great mathematical physicists of the world, having devoted many years to mathematical training. Pernicious it is because students are led to suppose that in later years they can atone for the neglect of their youth, and study fundamental subjects as the need arises. Helmholtz is a shining example of a man well prepared in fundamentals, whose preparation made possible for him the mathematical formulation and investigation of problems not before subjected to this analysis. His complete command of the tools prepared by mathematicians and physicists of preceding ages made Helmholtz a great contributor to modern civilization.

RUDOLF VIRCHOW—PATHOLOGIST[1]

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IN his delightful autobiography, the elder Gross[2] writes of his first European visit in 1868.

> There were three professional men in Berlin whom, as their names had long been familiar to me as household words, I was most anxious to see—Virchow, Langenbeck and Graefe. Accordingly, early in the morning of the second day after our arrival, I went to the Allgemeines Krankenhaus in search of Virchow, the illustrious pathologist and accomplished statesman, a professor in the university of Berlin, and a member of the German parliament. The great man, upon my entrance, was in the midst of his pupils, engaged in a post-mortem examination. As my presence attracted some attention, ... I deemed it my duty, although the moment was not the most opportune, to pass my card to the professor, at the same time apologizing for the intrusion. He at once saluted me with a gracious bow, and, shaking me cordially by the hand, introduced me to his pupils and expressed his gratification at seeing me. After a few minutes spent in conversation, he resumed his knife and completed his examination. He showed me his laboratory, his lecture-room, and many of his more interesting pathological specimens, most of them prepared by his own hands. His collections of diseased hearts of children, the result of inherited syphilis, is the largest in the world, and, as he explained specimen after specimen, he became not only enthusiastic but eloquent . . . . The laboratory, or work-shop as it may be termed, of Professor Virchow is a model in its way, admirably adapted to the wants of the student for improvement in the use of the microscope and the examination of morbid specimens. . . . Microscopes are provided in great numbers, and, in fact, every facility is afforded for the acquisition of knowledge. . . . . Such a room with the necessary appliances ought to exist in every well-organized medical institution in the United States.

Dr. Gross died in 1884, so that he lived to see but the slightest realization of this wish, which has now reached a degree of fulfilment beyond the greatest anticipation either of Virchow himself or of his contemporaries.

To continue Dr. Gross's personal narrative—and I can do no better in order to give an intimate acquaintance with him whose centennial we celebrate:

[1]A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

[2]Autobiography of Samuel D. Gross. G. Barrie, Philadelphia, 1887. Vol. I, p. 231-235.

Virchow is a most patient and laborious investigator and yet he never seems to be in a hurry. His dissections [autopsies][3] seldom occupy fewer than two and a half or three hours each. Every organ of the body is thoroughly explored. For years past his habit has been to open, every Monday morning, a cadaver in the presence of his private pupils with a view of instructing them in the art of conducting autopsies—holding the knife, using the saw, and taking notes, the whole being supplemented by microscopic inspections of the more important diseased structures. In these dissections he is, if possible, more patient even than Rokitansky, his great Viennese prototype.

Virchow is a thin, slender man, about the medium height, with a fine forehead, although the head is not large, and handsome black eyes, concealed by a pair of glasses. He is deliberate in his movements, a good talker, very affable, courteous and warm-hearted—in a word, a gentleman of the higher type.

The evening before Dr. Gross left Berlin he had further occasion to appreciate Virchow's splendid courtesy. While he was the guest of honor at Virchow's own table, together with von Langenbeck, von Graefe, the oculist, Donders, Gurlt and others, the host drew from under the table a large book, which proved to be the second edition of Gross's "Elements of Pathological Anatomy," and, rising, took his guest by the hand and in a graceful speech referred to the text as one from the study of which he had derived much useful instruction and one which he always consulted with much profit.

American medicine has too seldom received that full appreciation in Berlin and Vienna that Virchow was always willing to give. In reviews and abstracted articles edited by him one is struck by the large number of English and American references included.

Nearly twenty years after the visit of Gross to Berlin, we find Sir William Osler a pilgrim in Virchow's laboratory. Perhaps it has been the growing breadth of vision during those years, but not unlikely it is the wonderful catholicity of interests, possessed by the great visitor himself which changes the character of the pen picture. Part of his narrative I must reproduce even though it reaches beyond the limits of my subject. Osler[4] writes:

In 1884, on returning to Berlin for the first time since my student days, I took with me four choice examples of skulls of British Columbian Indians, knowing well how acceptable they would be. In his room at the Pathological Institute, surrounded by crania and skeletons, and directing his celebrated *diener*, who was mending Trojan pottery, I found the professor noting the peculiarities of a set of bones which he had just received from Madeira. Not the warm thanks, nor the cheerful, friendly greeting which he always had for an old student, pleased me half so much as the prompt and decisive identification of the skull which I had brought, and his rapid sketch of the cranial characters of the North American Indian. The profound expert, not

[3]Bracketed words are inserted by the author.

[4]Osler, William. Virchow, the man and the student, Johns Hopkins University Circulars, 1891, XI, 17-20.

the dilettante student has characterized all of his work in this line . . . As an illustration of his capacity for varied work, I recall one day in 1884, in which he gave the morning demonstration and lecture at the Pathological Institute, addressed the Town Council at great length on the extension of the canalization scheme, and made a budget speech in the House, both of which were reported at great length in papers of the next day.

Rudolf Virchow graduated in medicine from the Friedrich-Wilhelm Institute in 1843 with the dissertation *De rheumate praesertim corneae.* In the autumn of 1844, he became an assistant in pathological anatomy under Froriep, and in 1846 he was appointed prosector in the same clinic. He became a lecturer in the University of Berlin in 1847. Possessing vigorous political views, which would be considered liberal even today, he lost his university connections during the stormy period of 1848 and 1849, largely through the publication with Leubuscher of a half-medical, half-political journal, which they styled *Medicinische Reform.* From 1849 to 1856 he occupied the chair of pathological anatomy at Würzburg, where, working with the greatest industry, he raised his department to foremost rank and pursued investigations upon which much of his later work was based. At the end of that period, he was recalled to Berlin as professor of pathological anatomy and director of the newly established pathological institute in Berlin University, with which he was connected until his death.

To understand Virchow's relation to pathology and to medicine is to understand something of the stages through which scientific medicine has passed in the last one hundred and fifty years. We are now, and have been for some fifty years, in a period characterized by search for the etiological factor in disease. In part, the bacteriologist has been in the ascendency and we already have sufficient perspective to see the greatness of Pasteur and Koch. Among our contemporaries there may be those equally to be honored by another generation. Moreover, there are those who would have us believe that we are even now passing from the epoch of bacteriology into a period dominated by biochemistery, serology and immunology, but upon this transition, if, indeed, it should be dignified as such, light is still to be shed.

At any rate, these present-day tendencies will serve to illustrate the shifting emphasis in medical progress. Does it mean that the stage has been set for a certain scene, or that a brilliant and indefatigable worker, inspiring a group of collaborators, strides off into the unknown? As we read current medical history, the advance appears to be gradual and simultaneous along interdigitating lines. In retrospect, the advance assumes the topography of a series of steps rising from plateau-like surfaces. The highest step of the nineteenth century was the rise of microscopical pathology as established and developed by Rudolf Virchow.

Cellular pathology rose from a foundation of gross pathology. In the later half of the preceding century John Hunter had developed his wonderful museum of gross preparations of both normal and pathological anatomy. He had had the hardihood to apply objective experimental methods to the investigation of pathological problems. Through the experimental production of arterial anastomoses, he found that it was possible to ligate arteries whose flow had previously been considered essential to the life of a part. For Hunter, Virchow had the greatest admiration, and it has been said that for a long time Hunter's picture alone was found upon the walls of his laboratory. Fifty years or so after Hunter, Rokitansky in Vienna brought the period of gross pathology to its greatest height. The first autopsy protocol written in his own hand is dated October 23, 1827. In March, 1866, he achieved his thirty thousandth post-mortem examination. It is said that before his death he had access to 100,000 protocols of autopsies done by himself and his assistants. With this enormous material he brought descriptive gross pathology to a degree of perfection never before realized.

As will be noted by the dates just given, Rokitansky was well established in his field of gross pathology when Virchow read his inaugural dissertation. In fact, Virchow was still in his assistantship when the first volume of Rokitansky's *Lehrbuch der pathologischen Anatomie* appeared in 1845. With the microscope at his disposal, his independence of thought, his originality in attack, and, above all, his ability to exalt pure objective description as an end in itself made it possible for Rudolf Virchow to do for the pathology of the cell what Rokitansky had done for the pathology of the organ and tissue.

All medicine before Virchow had been burdened with mysticism, dogma and hypothesis. Witness the pertinacity with which the humoral theory survived in its varying forms, even to the extent of obscuring the earlier part of Rokitansky's work. All this Virchow was able to cast aside and, avoiding dogma, he developed a method rather than a theory.

To those who would lessen the importance of Virchow's work by reference to Bichat, it need but be said that while the latter did resolve the various organs and tissues of the body into twenty-one simple, and, as he supposed, elemental types, this analysis was done on the basis of naked-eye observation alone. Bichat did not use the microscope. Like Virchow, however, he placed the objective detailing of facts before speculation. To Schleiden and Schwann, Virchow gave full credit for the earlier development of the idea of the animal cell as interpreted in terms of cellular botany. Yet, it must be remembered that to a great extent Virchow was called upon to formulate for himself standards of normal histology as well as to describe the changes produced in the cell by disease.

No adequate analysis of Virchow's published work can be given here. Its volume is remarkable. In 1901, Schwalbe[5] and others whose assistance he invited, compiled a Virchow bibliography as their part in the celebration of the eightieth birthday of their old master. In the preface, Schwalbe himself says that a Virchow bibliography lays bare not alone the life-work of a man, but exposes as well a history of medicine and anthropology for the preceding sixty years. Requiring 118 pages, with an average of about eighteen items to the page, this list of approximately 2,000 titles bears witness to the industry, breadth of interest and critical scientific discrimination of the cellular pathologist. From all of this material I can refer only to the two most important books, to the journals developed under his leadership and to a few of the most important articles.

"Die Cellularpathologie" appeared in 1858. This book, presented in the form of twenty lectures illustrated by numerous wood cuts, placed before the world for the first time a summation of the author's views. Here was demonstrated that the principle of *omnis cellula e cellula*, which he was first to put into words, applied equally to pathological formations and to normal embryologic development. Translated into French by Picard and into English by Frank Chance, "Cellular Pathology" was seized upon with an avidity which must have surprised even its author. From that year modern pathology is to be dated. We cannot appreciate the effect upon Medicine of this new point of view. Before, all morbid products, tumors, cancers, purulent collections, tubercles, gummas had been explained as arising in, or from, a hypothetical primitive blastema, itself exudative in nature. Now these were shown to be composed of living body cells, differing in various ways from the normal, exhibiting alterations both in form and function. With histological technique in its infancy, much was incomplete and misinterpretations were bound to occur, even as they do to-day.

Let me illustrate the accuracy of observation shown in the "Cellular Pathology" by quotations dealing with the subject of argyria, the deposit of silver pigment in the tissues. Every student of pathology now knows that argyriasis shows a selective affinity for the fibrillae of connective tissue. Silver is not deposited in epithelial structures, although it usually gains entrance to the body by passing through an epithelium. Note how clearly Virchow states these facts.

> We know that when any one takes salts of silver, they penetrate into the different tissues of his body. . . . A patient who had . . . received a solution of nitrate of silver as a lotion [for the eyes], very conscientiously employed the remedy . . . ; the result of which was that his conjunctiva

[5]Schwalbe, J. Virchow-Bibliographie, 1843-1901. G. Reimer, Berlin, 1901. Pp. 183.

assumed an intensely brown, nearly black appearance. The examination of a piece cut out of it showed that silver had been taken up into the parenchyma, and indeed in such a manner that the whole of the connective tissue had a slightly yellowish brown hue upon the surface, whilst in the deeper parts the deposition had taken place only in the fine elastic fibers of the connective tissue, the intervening parts, the proper basis-substance, being perfectly free. But deposits of an entirely similar nature take place also in more remote organs. Our collection contains a very rare preparation from the kidneys of a person who on account of epilepsy had taken nitrate of silver internally. In it may be seen the Malpighian bodies, in which the real secretion takes place, with a blackish blue coloring of the whole of the membrane of the coil of the vessels, limited to this part of the cortex, and appearing again, in a similar, though less marked form, only in the intertubular stroma of the medullary substance. . . . . The salts of silver do not deposit themselves in the lungs [when present in the circulating blood], but pass through them to be precipitated only when they reach the kidneys or the skin.

Taking second place in importance among the larger works of Virchow, is the three volume treatise on tumors, "Die Krankhaften Geschwülste." This was completed in the years 1863-1867. In it Virchow develops a systematic classification of neoplasms based largely upon their microscopical characteristics. Here the influence of his teacher, Johannes Müller, is evident. The terminology used by Virchow in this work still survives to a large degree.

Of the great array of lesser works, I can mention but a few groups. In the late forties Virchow, published a series of epoch-making papers on disturbances of the circulation. Here for the first time phlebitis, thrombosis, metastasis and embolism were clearly set forth. In fact, the term Embolia, or as we now say, embolism, was introduced by Virchow himself. Osler relates that in 1848, at the height of Virchow's political activity, he performed an autopsy upon a patient, said by Schönlein to have died from cerebral hemorrhage. Virchow found no hemorrhage, but succeeded in demonstrating an embolus blocking an important cerebral artery. Schönlein, who was present to see the outcome of his diagnosis, turned to Virchow and in a half-joking, half-vexed manner, said *Sie sehen auch überall Barricaden.* Other important monographs, papers and groups of papers were those dealing with calcium metastasis, pathological pigmentation, amyloid, leukaemia, chlorosis, phosphorus poisoning, syphilis, trichinosis, rickets, cretinism, encephalitis and peptic ulcer. The list might be much extended.

In 1847, Virchow with Reinhardt founded the *Archiv für pathologische Anatomie und Physiologie und für klinische Medicin.* This journal has been continued since that time, and constitutes the most important collection of original contributions to scientific medicine. After Reinhardt's death in 1852, Virchow carried the editorship alone for many years, so that even now one finds as many citations to this journal by the phrase "Virchow Archiv" as by its proper title. From 1851 to 1893

he was the joint editor, and from 1893 to 1901 the sole editor, of Canstatt's *Jahresbericht über die Leistungen und Fortschritte in der gesammten Medicin.* From 1850 to 1862, Virchow shared with Kölliker, Scherer and Scanzoni the editorship of the *Verhandlungen der physikalisch-medicinischen Gesellschaft in Würzburg.*

A list of Virchow's pupils would include most of the makers of medicine of the last fifty years. Scattered throughout the civilized world, they have from time to time brought together in *Festschriften* and memorial celebrations lists of names and collections of original contributions of which their old master may well have been proud. The *Festschrift* for his seventy-first birthday contributed by his former, and then acting, assistants in the Berlin Pathological Institute includes in its table of contents the names of v. Rechlinghausen, Klebs, Salkowski, Orth, Grawitz and Langerhans, among others, all of whom have had a great influence on the development of pathology and modern medicine. American medicine owes much to those who were under Virchow's tutelage in the last three decades of the nineteenth century.

Virchow was wrong. The cell is not the ultimate unit of life, but the methods of cellular pathology have grown no less important since he gave his great work to the world. The cell with its miscroscopically demonstrable content is still the morphological unit of life. Disease processes are still interpreted in the light of the cellular changes.

To Virchow we owe our conception of disease. Disease is not an entity, entering the body from without. Disease is life, life which deviates from the normal. The casual factor may reside within or may come from without in the form of trauma, infection, intoxication, or what not, but the cause is not the disease. The disease is the abnormal life of the body cells. The methods of modern medicine are therefore broadly biologic, and along this road of promise Rudolf Virchow pointed the way.

RUDOLF VIRCHOW—ANTHROPOLOGIST AND ARCHEOLOGIST[1]

By Professor ARTHUR E. R. BOAK
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RUDOLF LUDWIG KARL VIRCHOW was born in the little Pomeranian town of Schivelbein, on October 13, 1821. He died on September 5, 1902. His parents were people in moderate circumstances, his father combining the occupation of a farmer with that of a retail merchant. The young Virchow received his early education at the parochial school of Schivelbein, with special instruction from the local clergymen. He then entered the gymnasium at Köslin, from which he graduated in 1838 at the age of seventeen.

At the gymnasium he followed the regular classical program of studies, but showed at the same time great enthusiasm for the natural sciences, history and geography. He acquired and retained throughout life a remarkable accuracy in both Greek and Latin, and in his later years upon several occasions mercilessly criticized the barbarisms which the younger generation attempted to introduce into medical terminology. This same attention to accuracy of details characterized Virchow's work in every field, and gave him the perfectly astounding mass of information which rendered him such a deadly critic of unstable hypotheses. In addition to the study of the classics, Virchow found time at the gymnasium to read widely in the French and German classics. Italian and English he acquired later. It is interesting to have his reflections upon suitable courses of study for the gymnasium, expressed in an address delivered when rector of the University of Berlin. He maintained that, as a preparation for scientific work, a course in mathematics, philosophy and the natural sciences would have equal value with a classical course, but that the later could not be replaced by the modern languages.

From the gymnasium at Köslin, Virchow proceeded to the Royal Medico-Surgical Friedrich Wilhelm's Institute at Berlin. Here he qualified for the doctorate in 1843. In connection with his inaugural dissertation, Virchow defended, among other theses, two which he afterwards looked upon as showing the early ripeness of his intellect and the breadth of his interests. The first of these ran *nisi qui liberali-*

[1] A paper read at a meeting of the Research Club, University of Michigan, April 20, 1921, in commemoration of the centennials of Hermann von Helmholtz and Rudolph Virchow.

bus rebus favent veram medicinae indolem non cognoscunt (Those who do not encourage progress do not grasp the true nature of medicine); the second was an application of Agassiz's then recently published glacial theory to Pomerania *Pomeraniae petrificata glacie primordiali disiecta.* To Virchow there might fittingly be applied the saying, *homo sum, et nihil humanum mihi alienum puto.* His ability to connect science with life as a whole and his interest in everything pertaining to life led him from the investigation of the dead to that of the living man, from craniology to ethnology and to the history of civilization, as well as from the laboratory into the political arena.

In full conformity with this atitude towards life was Virchow's report upon the typhus epidemic in Silesia, published in 1848. Here he showed that the source of the epidemic was to be found in the backward social and political conditions of Silesia, and made radical suggestions for their amelioration. The championship of the people which he thus assumed he maintained throughout a long political career, as a member of the Prussian House of Representatives, from 1862 to 1878; of the Reichstag, from 1880 to 1893; and of the municipal council of Berlin for 42 years. He was a founder of the progressive party (*Fortschrittspartei*), and a firm opponent of Bismarck's imperialism, being honored by the latter with a challenge to a duel. He fought unceasingly for the improvement of the education as well as the social conditions of the masses, and the term *Kulturkampf* was an outgrowth of his political manifestoes. But, at the close of his life, it was Virchow's boast that, although he had devoted himself to both politics and medicine, he had always succeeded in preserving for science its independence of political influences.

While a professor at the University of Würzburg (1849-56), Virchow published two studies on cretinism in Lower Franconia and pathological skull forms (1851-2). These may be taken to mark the beginning of his anthropological work, and were the first of more than one thousand publications in this and allied fields. They were followed (1857) by his "Investigations on the Development of the Base of the Skull in Healthy and Diseased Conditions, and on the Influence of the same upon Skull Form, Facial Structure and Brain Formation." In this treatise he laid the foundation for an anatomical treatment of craniology, pointing out as the problem for investigation the relationship between the shape of the skull, the facial structure and the formation of the brain. His conclusion was that all typical variations in facial structure rest chiefly upon differences in the formation of the base of the skull.

For about a decade following his return to Berlin in 1856, Virchow's main interest and activity lay in the field of medicine. Then he began to turn his attention in an ever increasing degree to anthropological and allied studies, upon which he entered with all the enthusiasm of a true

pioneer. In 1869, mainly through his efforts, was organized the Deutsche Anthropologische Gesellschaft. In the same year he founded the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte, and its organ the *Zeitschrift für Ethnologie*. In addition to directing the publication of the *Zeitschrift*, he was also an editor of the *Correspondenzblatt* of the Anthropologische Gesellschaft and, from 1870, of the *Archiv für Anthropologie*. The degree to which these new fields absorbed Virchow's activities may be gathered from the fact that, although it was as a pathologist that he was elected to the Royal Academy of Sciences at Berlin in 1874, only three of his numerous papers read before the academy dealt with problems of pathology, while nearly all the rest discussed anthropological subjects.

Passing from the study of the diseased to that of the normal skull, in 1874 Virchow presented the results of his attempts to find ethnognomic skull characteristics in an article entitled "On Some Characteristics of the Skulls of the Lower Races of Man." Here he advanced the generally accepted view that the frontal projection of the squamous portion of the temporal bone is a pithecoidal characteristic, much more frequent among non-Aryan than Aryan peoples; and that the unproved, but certainly to be suspected, defective formation of the temporal brain parts as a result of this frontal projection permits us to see in the latter, and in the bare narrowing of the temporal area, a mark of lower, but not necessarily of the lowest, races.

Virchow's next efforts were directed towards the determination of the skull types of European races. Here the prevailing view was that of Retzius: that each of the great racial divisions had a single type of skull and that peoples must be differentiated as either dolicocephalic or brachycephalic. Virchow took a more cautious attitude and opposed the selection of type skulls "until the whole breadth of individual varieties was known." He also combatted Nilson's theory that an original brachycephalic European population had been overrun by a dolichocephalic element which stood upon a higher plane of physical and mental development, *i. e.*, the Celts and the Germans.

In 1875, Virchow declared it impossible to establish definite craniological types for Germans, Celts, Slavs, Finns or Italians; that the postulate of originally pure and homogeneous great culture races is erroneous, and that all these have been formed by a mixture of smaller elements, a view which now receives general acceptance. Then, in the following year, in his "Contributions to the Physical Anthropology of the Germans," he claimed that even greater weight should be laid upon the height of the skull than upon its length or breadth, and he was able to show that the old German cranial type, as represented by the Frisians, were chamaeprosopic and mesocephalic rather than dolichocephalic as had been maintained heretofore.

The scope of Virchow's anthropological studies widened until he sought to give an exact descriptive basis for the natural history of man. Hence he directed his investigations toward living peoples, as well as toward those which are now extinct, and entered upon the field of ethnology. One great result of his efforts was the census of the school children of the German Empire, taken from the point of view of racial physical characteristics. This census brought out the fact that the historic characteristics of the old Germanic type—blond hair, white skin and blue eyes—were to be found united in only approximately one third of the population of Prussia and one fifth of that of Barvaria. Perhaps in this connection one should mention Virchow's establishment in 1888 of the Museum for German National Costumes and Products of Household Industry, at Berlin.

Carrying his investigations outside of Germany, Virchow compiled anthropological analyses of the Lapps, Eskimos, Patagonians, Terra del Fuegians, Kaffirs, Australians and Malays. One of his most interesting studies was that of the population of Ceylon, in which he established the nanocephalism and racial purity of the Veddas, as well as their relationship to the older Dravidian or pre-Dravidian population of India, while showing that the Cingalese, on the contrary, were a mixed race.

Virchow continued his craniological studies with unabated zeal until the time of his death, when his collection comprised some 4,000 skulls, ancient and modern, coming from all quarters of the globe. Yet he had to acknowledge his inability to attain a satisfactory craniological differentiation of races, or an explanation of how various skull types arise among the same people. He gave great attention to the development of more exact methods of craniological measurements, and helped to bring about the adoption of standard systems in this field. Another beneficial result of his work in this field was the exclusion of pathological forms from the list of skull types. Here it may be mentioned that he maintained that the celebrated Neanderthal skull exhibited pathological characteristics, and consequently protested against the acceptance of a distinct racial type upon the evidence of this single specimen. But in this he failed to win the support of the majority of anthropologists.

In addition to studies upon Illyrian, Trojan, Cyprian, Moroccan, East African, Ancient and Modern Greek, and Philippine skull types, Virchow published a work on American racial skulls—Crania Ethnica Americana—noteworthy both for its descriptive details and for its differentiation of pathological deformities of the skull from artificial deformities resulting from accident or intent. His examination of the remains of the Java ape-man—*pithecanthropus erectus* Dubois—led him to the conclusion that it did not belong to the genus homo, but was a gibbon of an extinct species, a view which now finds little acceptance.

It was inevitable that Virchow should be attracted by the basic problems of anthropology and biology, such as the origin of species and the place of man in the natural world. And it was natural that his point of view in these questions should depend upon his belief in the identity of physiological and pathological processes. His formula was: Individual and type equal pathology and physiology. Towards the Darwinian theory of evolution he was by no means hostile, but exhibited the same cautious attitude as in other anthropological questions. He held that there was a great gap in our knowledge, namely, in regard to the development of the human from the lower forms of life. For the time this gap may certainly be filled by an hypothesis, for only by hypotheses can the path of research in unknown fields be marked out. Such a hypothesis, Virchow felt, Darwin had supplied in the finest sense of the word. "It was an immeasurable advance," he declared, "which living Nature made when the first man developed from an animal, whether that was an ape or other creature, which was the racial ancestor of the ape as well. However, the actual proof of the descent of man from the ape has not yet been made. None of the known apes supplies the transitional stage." Still the theory of the descent of man was for him, "not only a logical, but also a moral postulate," whose value lies not in being a new dogma, but a light for further research.

His attitude came to light clearly in his famous controversy with Haeckel, in 1887, when the latter demanded that his monistic doctrine be introduced into the schools. Virchow objected strenuously to the teaching of the problems as though they were the conquests of science, taking the ground that this was contrary to the conscience of the natural scientist, who reckons only with facts. He likewise protested vigorously against any form of compulsion of conscience.

In approaching the problem of the origin of species, Virchow saw more hope of attaining a solution through physiology and pathology than through morphology, which gives only the possibility and not the proof of evolution. "He who teaches us," he wrote, "to develop a Schimmelpilz out of a Spaltpilz will have accomplished more than all the heralds of the geneological tree of man."

In his "Rassenbildung und Erblichkeit" (1896), he developed his doctrine of the pathological nature of variations from type. Originally each species, or variation from type, is produced by a permanent disturbance of the parental organism, and is in this sense pathological. Only by inheritance in the descendants does this condition become physiological: but, up to now, it is completely unknown why one disturbance is inherited, another not. Races, too, are only hereditary species, which rest upon a pathological disturbance in the parental organism. Probably in most cases the disturbance is produced by the environment, but often also by causes contained within the organism, which become effective only after birth.

Virchow's general interest in historical questions and his special anthropological studies led him into the field of prehistoric archeology. To this study, in Germany, he did a great service by raising it from dilettantism to a recognized position among the social sciences. He was early attracted by the history of his birthplace, Schivelbein, and, in 1866, wrote on its antiquities. From 1867 onwards, he became a regular participant in the international congresses for prehistoric archeology and anthropology. In 1869, he began his investigations of North German pile dwellings. A careful study of ceramics enabled him to determine that these pile dwellings were of later origin than the corresponding structures in South Germany, and, on the basis of similar evidence, he showed that the so-called Wendish cemeteries were really pre-Slavic in origin.

Becoming interested in the question of the mutual influences of prehistoric cultures, Virchow made an exhaustive study of the ancient amber and flint traffic routes in Central Europe. It was largely as a result of a friendship formed in 1875 with the Homeric enthusiast Schliemann that Virchow extended his archeological studies beyond the limits of his native country. In 1879 he accompanied Schliemann to the site of ancient Troy, in 1881 to the Caucasus, and in 1888 to Egypt, Nubia and the Peloponnesus. It was Virchow's influence that induced Schliemann to entrust his later excavations at Troy to the experienced archeologist Dörpfeld.

Virchow's expedition to the Caucasus was undertaken in the hope of finding there the source of the European bronze age culture, but in his report on the Graveyard of Koban (1883) he decided against the possibility of this theory. One important result of his work in Egypt was that he was the first to adduce positive evidence for a period of neolithic culture in the Nile Valley.

His Caucasian studies led Virchow to encourage others to interest themselves in the origins of the civilization of the Near East, and through the work of his pupils the civilization of the ancient kingdom of Colchis was revealed. Shortly before his death, Virchow had assumed the honorary direction of a new German Society for the Investigation of Asia Minor, especially Anatolia and Cappadocia.

In these closely related fields of anthropology, ethnology and prehistoric archeology, Virchow's fame rests not so much upon the infallibility of his own conclusions as upon his introduction of scientific methods of investigation, his establishment of organizations for cooperative effort in research, his logical and independent thinking and his deep sense of truth. A great worker himself, he stimulated the work of others, not only in his own country, but also abroad, and so became, in the best sense of the word, an international figure.

THE BIOLOGY OF DEATH—V. THE INHERITANCE OF DURATION OF LIFE IN MAN[1]

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1. The Determination of Longevity

IN the series of papers up to this point we have seen, in the first place, that immortality is a potential attribute of cells generally and becomes actually realized when conditions are so arranged as to make continued life possible. These conditions are not realized in the metazoan body because of differentiation and specialization of structure and function. What actually happens in the metazoa is that sooner or later some differentiated organ or system of organs gets to functioning badly and upsets the delicate balance of the whole. As a result the entire organism presently dies. We have further seen that in the case of man, where alone quantitative data are available, the breakdown of particular organ systems, and consequent death of the whole, occurs in a highly orderly manner in respect of time or age. Each organ system has a characteristic time curve for its breakdown, differing from the curve of any other system. The problem which now confronts us is to find out what lies back of these characteristic time curves and determines their form. In view of the biological facts about death which we have learned, what determines that John Smith shall die at 58, while Henry Jones lives to the obviously more respectable age of 85? We have seen that there is every reason to believe that all the essential cells of both their bodies are inherently capable under proper conditions of living indefinitely. We are further agreed that it is the differentiated and specialized structure of their bodies which prevents the realization of these favorable conditions. But all this helps us not at all to understand why in fact one lives nearly 30 years longer than the other.

It may help to visualize this problem of the determination of longevity to consider an illustrative analogy. Men behave in respect of their duration of life not unlike a lot of eight-day clocks cared for by an unsystematic person, who does not wind them all to an equal degree and is not careful about guarding them from accident. Some he winds up fully, and they run their full eight days. Others he winds only half way and they stop after four days. Again the clock which

[1]Papers from the Department of Biometry and Vital Statistics. School of Hygiene and Public Health, Johns Hopkins University, No. 32.

has been wound up for the full eight days may fall off the shelf and be brought to a stop at the third day. Or someone may throw some sand in the works when the caretaker is off his guard. So, similarly, some men behave as though they had been wound up for a full 90-year run, while others are but partially wound up and stop at 40 or 65, or some other point. Or, again, the man wound up for 80 years may, like the clock, be brought up much short of that by an accidental invasion of microbes, playing the rôle of the sand in the works of the clock. It is of no avail for either the clock or the man to say that the elements of the mechanism are in whole or in major part capable of further service. The essential problem is: what determines the goodness of the original winding? And what relative part do external things play in bringing the running to an end before the time which the original winding was good for? It is with this problem of the winding up and running of the human mechanism that the present paper will deal.

There are two general classes of factors which may be involved here. These are, on the one hand, heredity and, on the other hand, environment, using the latter term in the broadest sense. Inasmuch as we can be reasonably sure on *a priori* grounds that longevity, like most other biological phenomena, is influenced by both heredity and environment, the problem practically reduces itself to the measuring of the relative importance of each of these two factor groups in determining the results we see. But before we start the discussion of exact measurements in this field, let us first examine some of the general evidence that heredity plays any part at all in the determination of longevity.

2. The Hyde Family

The first material which we shall discuss is that provided by the distinguished eugenist, Dr. Alexander Graham Bell, in his study of the Hyde family. Every genealogist is familiar with the "Genealogy of the Hyde Family," by Reuben H. Walworth. It is one of the finest examples in existence of careful and painstaking genealogical research. Upon the data included in this book, Bell has made a most interesting and penetrating analysis of the factors influencing longevity. At first thought one might conclude that highly biased results would probably flow from the consideration of only one family. Bell meets this point very well, however, in the following words:

> A little consideration will show that the descendants did not constitute a single family at all, and indeed had very little of the Hyde blood in them.
>
> Even the children of William Hyde owed only half of their blood to him, and one-half to his wife. The grandchildren owed only one-quarter of their blood to William Hyde, and three quarters to other people, etc. The descendants of the seventh generation, and there are hundreds of them, owed only one sixty-fourth of their blood to William Hyde, and sixty-three sixty-fourths to the new blood introduced through successive generations of marriages with persons not of the Hyde blood at all.

It will thus be seen that the thousands of descendants noted in the Hyde Genealogy constitute rather a sample of the general population of the country than a sample of a particular family in which family traits might be expected to make their appearance.

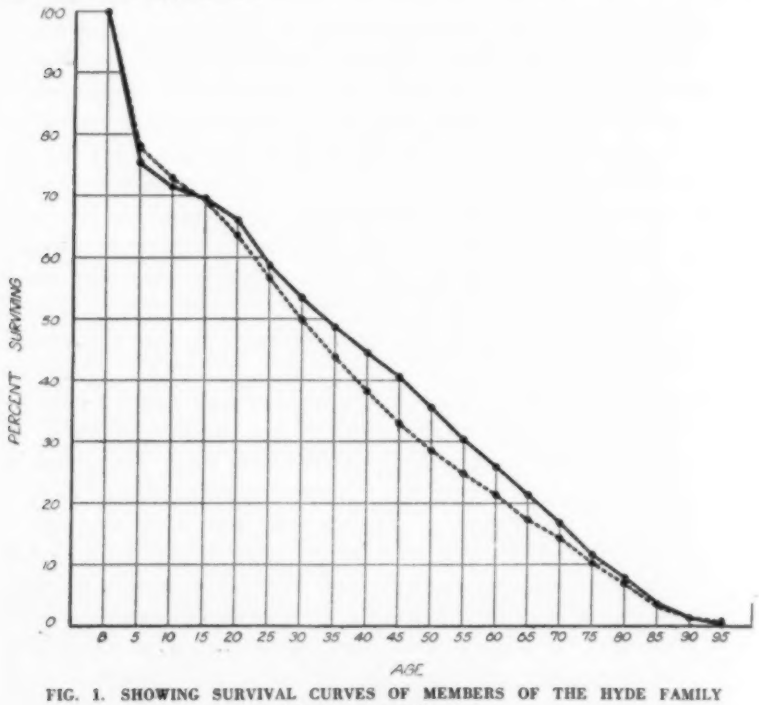

FIG. 1. SHOWING SURVIVAL CURVES OF MEMBERS OF THE HYDE FAMILY (Plotted from Bell's data)

The substantial normality of the material is shown in Figure 1, which gives the l_x line, that is, the number of survivors at each age, of the 1,606 males and 1,352 females for whom data were available. The solid line is the male l_x line and the dotted line the female l_x. It is at once apparent that the curves have the same general sweep in their passage over the span of life as has the general population life curve discussed in the preceding paper. The descent is a little steeper in early adult life. The female curve differs in two respects from the normal general population curves. In the first place, beginning at age 15 and continuing to age 90, the female curve lies below that for the males, whereas normally for the general population it lies above it. This denotes a shorter average duration of life in the females than in the males, the actual figures being 35.8 years for the males and 33.4 years for the females. Bell attributes the difference to the strain of child-bearing by the females in this rather highly fertile group of people, belonging in the main to a period when restrictions upon size of family were less common and less extensive than now. In the second place, the female l_x curve is actually convex to the base through-

out a considerable portion of middle life whereas normally this portion of the curve presents a concave face to the base.

Apart from these deviations, which are of no particular significance for the use which Bell makes of the data, the Hyde material is essentially normal and similar to what one would expect to find in a random sample of the general population. In this material there were 2,287 cases in which the ages at death of the persons and the ages at death of their fathers were known. It occurred to Bell to arrange this material in such a way as to show what, if any, relation existed between age at death of the parent and that of the offspring. He arranged the parents into four groups, according to the age at which they died, and the offspring into five groups upon the same basis. In the case of the parents the groups were: First, those dying under 40;

TABLE I

Analysis of the Hyde family data by person's age at death, showing the number and percentage having (a) fathers and (b) mothers who died at the age periods named. (From Bell).

Person's age at death	Father's age at death				
	Stated	-40	40-60	60-80	80+
Stated	2,287	66	522	1,056	643
Under 20	669	20	189	299	161
20 and under 40	538	18	140	269	111
40 and under 60	467	12	116	215	124
60 and under 80	428	13	57	196	162
80 and over	185	3	20	77	85
Percentages					
Stated	100.0	2.9	22.8	46.2	28.1
Under 20	100.0	3.0	28.2	44.7	24.1
20 and under 40	100.0	3.4	26.0	50.0	20.6
40 and under 60	100.0	2.6	24.8	46.0	26.6
60 and under 80	100.0	3.0	13.3	45.8	37.5
80 and over	100.0	1.6	10.8	41.6	46.0
Person's age at death	**Mother's age at death**				
	Stated	-40	40-60	60-80	80+
Stated	1,805	191	435	713	466
Under 20	511	88	129	199	95
20 and under 40	407	42	104	176	85
40 and under 60	379	27	92	159	101
60 and under 80	360	26	80	129	125
80 and over	148	8	30	50	60
Percentages					
Stated	100.0	10.6	24.1	39.5	25.8
Under 20	100.0	17.2	25.2	39.0	18.6
20 and under 40	100.0	10.3	25.6	43.2	20.9
40 and under 60	100.0	7.1	24.3	42.0	26.6
60 and under 80	100.0	7.2	22.2	35.9	34.7
80 and over	100.0	5.4	20.3	33.8	40.5

second, between 40 and 60; third, between 60 and 80; and fourth, at age 80 and over. The groups for the offspring were the same, except that the first was divided into two parts, namely, those dying under 20 and those dying between 20 and 40. The resulting figures are exhibited in Table 1.

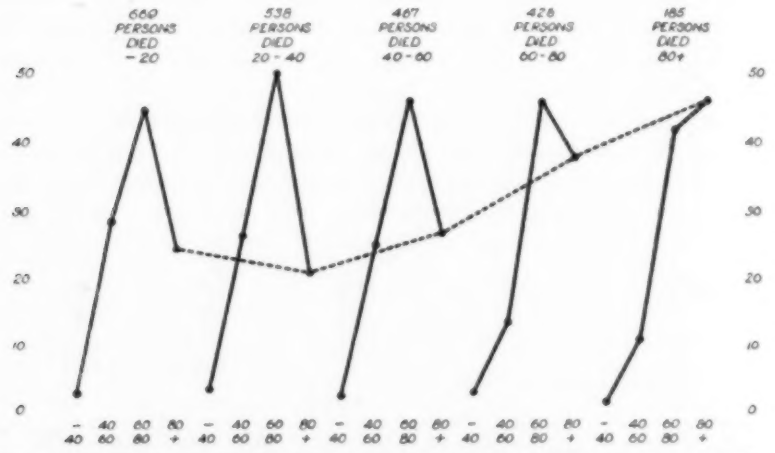

FIG. 2. INFLUENCE OF FATHER'S AGE AT DEATH UPON LONGEVITY OF OFFSPRING. First dot in each diagram shows the percentage having fathers who died at 40; second dot the percentage having fathers who died from 40—60; third dot the percentage having fathers who died from 60—80; fourth dot the percentage having fathers who died 80+

The results for father and offspring are shown in Figure 2, based upon the data of Table 1. In each of the 5 polygons, one for each offspring group, the first dot shows the percentage of fathers dying under 40; the second dot the percentage of fathers dying between 40 and 60; and so on, the last dot in each curve showing the percentage of fathers dying at age 80 and over. It is to these last dots that attention should be particularly directed. It will be noted that the dotted line connecting the last dots of each of the 5 polygons in general rises as we pass from the left-hand side of the diagram to the right-hand side. In the case of offspring dying under 20, 24 per cent. of their fathers died at ages over 80. About 21 per cent. of the fathers of offspring dying between 20 and 40 lived to be 80 years or over. For the next longer-lived group of offspring, dying between 40 and 60, the percentage of fathers living to 80 or over rose to 27 per cent. In the next higher group, the percentage is nearly 38, and finally the extremely long-lived group of offspring, the 185 persons who died at ages of 80 and over, had 46 per cent. or nearly one half of their fathers living to the same great age. In other words, we see in general that the longer-lived a group of offspring is, on the average, the longer-lived are their fathers, on the average; or, put in another way, the higher the percentage of very long-lived fathers which this group will have as compared with shorter-lived individuals.

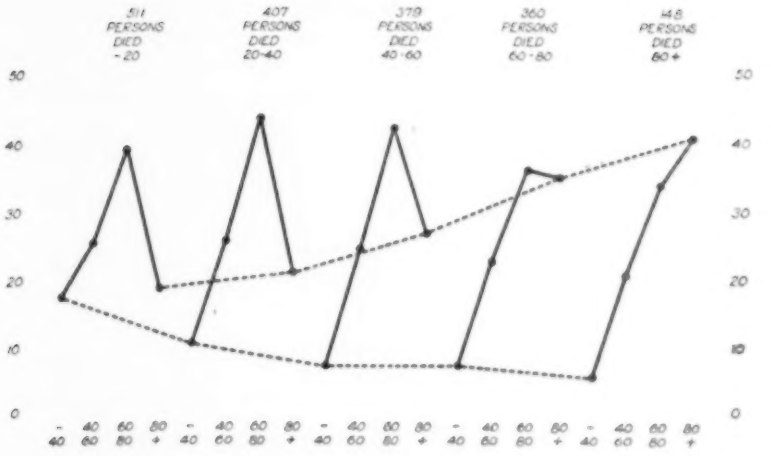

FIG. 3. INFLUENCE OF MOTHER'S AGE AT DEATH UPON LONGEVITY OF OFFSPRING. First dot in each diagrom shows the percentage having mothers who died at 40; second dot the percentage having mothers who died at 40—60; third dot the percentage having mothers who died 60—80; fourth dot the percentage having mothers who died 80+

Figure 3 shows the same sort of data for mothers and offspring. Here we see the curve of great longevity of parents rising in an even more marked manner than was the case with fathers of offspring. The group of offspring dying at ages under 20 had only 19 per cent. of their mothers living to 80 and over, whereas the group of offspring who lived to 80 and beyond had 41 per cent. of their mothers attaining the same great age. At the same time we note from the dotted line at the bottom of the chart that as the average age at death of the offspring increases, the percentage of mothers dying at early ages, namely, under 40, as given by the first dots, steadily *decreases* from 17 per cent. at the first group to just over 5 per cent. for the offspring dying at very advanced ages.

These striking results demonstrate at once that there is a definite and close connection between the average longevity of parents and that of their children. Extremely long-lived children have a much higher percentage of extremely long-lived parents than do shorter lived children. While the diagrams demonstrate the fact of this connection, they do not measure its intensity with as great precision as can be obtained by other methods of dealing with the data. A little farther on we shall take up the consideration of this more precise method of measurement of the hereditary influence in respect of longevity.

In the preceding diagrams we have considered each parent separately in connection with the offspring in regard to longevity. We shall, of course, get precisely the same kind of result if we consider both parents together. For the sake of simplicity, taking only the

cases of extreme longevity, namely, persons living to 80 or over—the essential data are given in Table 2.

TABLE 2

Longevity of parents of persons dying at 80 and over. (From Bell).

Age at death of parents	Number of persons	Number of persons lived 80+	Per cent. of persons lived 80+
Stated	1,594	139	8.7
Lived to be 80+			
Neither parent.....	827	44	5.3
One parent (not other)...	583	57	9.8
Both parents.....	184	38	20.6
Father (not mother).....	337	38	11.3
Mother (not father).....	246	19	7.7

From this table it is seen that where neither parent lived to be 80, only 5.3 per cent. of the offspring lived to be 80 or over, the percentage being based upon 827 cases. Where one parent, but not the other, lived to be 80 or older, 9.8 per cent. of the offspring lived to be 80 or older, the percentage here being based upon 583 cases. Where both parents lived to be 80 or older 20.6 of the persons lived to the same great age, the percentage being based upon 184 cases. Thus it appears that in this group of people four times as many attained great longevity if both of their parents lived to an advanced age, as attained this age when neither parent exhibited great longevity. The figures from the Hyde family seem further to indicate that the tendency of longevity is inherited more strongly through the father than through the mother. Where the father, but not the mother, lived to be 80 or older, 11.3 per cent. of the persons lived to age 80 or more, there being 337 cases of this kind. Where the mother, but not the father, lived to be 80 or older, only 7.7 per cent., or nearly 4 per cent. fewer of the persons lived to the advanced age of 80 or more, there being 246 cases of this sort. Too much stress is not, however, to be laid upon this parental difference because the samples after all are quite small.

One other point in this table deserves consideration. Out of the 1,594 cases as a whole, less than 9 per cent. of the persons lived to the advanced age of 80 or more. But out of this number there are 767, or 48.1 per cent., nearly one-half of the whole, who had parents who lived to 80 or more years.

Another interesting and significant way in which one may see the great influence of the age of the parents at death upon the longevity of the offspring, is indicated in Table 3, where we have the average duration of life of individuals whose fathers and mothers died at the specified ages.

TABLE 3

Showing the influence of a considerable degree of longevity in both father and mother upon the expectation of life of the offspring. (After Bell). (In each cell of the table the open figure is the average duration of life of the offspring and the bracketed figure is the number of cases upon which the average is based).

Father's age at death	Mother's age at death		
	Under 60	60-80	Over 80
Under 60	32.8 years (128)	33.4 years (120)	36.3 years (74)
60-80	35.8 (251)	38.0 (328)	45.0 (172)
Over 80	42.3 (131)	45.5 (206)	52.7 (184)

We see that the longest average duration of life, or expectation of life, was of that group which had both mothers and fathers living to age 80 and over. The average duration of life of these persons was 52.7 years. Contrast this with the average duration of life of those whose parents both died under 60 years of age, where the figure is 32.8 years. In other words, it added almost exactly 20 years to the average life of the first group of people to have extremely long-lived parents, instead of parents dying under age 60. In each column of the table the average duration of life advances as we proceed from top to bottom—that is, as the father's age at death increases—and in each row of the table the average expectation of life of the offspring increases as we pass from left to right—that is, with increasing age of the mother at death. However the matter is taken, a careful selection of one's parents in respect of longevity is the most reliable form of personal life insurance.

So much for Bell's analysis of longevity in the Hyde family. We have seen that it demonstrates with the utmost clearness and certainty that there is an hereditary influence between parent and offspring affecting the expectation of longevity of the latter. Bell's method of handling the material does not provide any precise measure of the intensity of this hereditary influence, nor does it furnish any indication of its strength in any but the direct line of descent. Of course, if heredity is a factor in the determination of longevity we should expect its effects to be manifested as between brothers and sisters, or in the avuncular relationships, and in greater or less degree in all the other collateral and more remote direct degrees of kinship. Happily, we have a painstaking analysis, with a quantitative measure of the relative influence of heredity in the determination of longevity, which was carried out many years before Bell's work on the Hyde family, by the pioneer in this field, Prof. Karl Pearson. His demonstration of the inheritance of longevity appeared more than twenty years before that of Bell. I have called attention to the latter's work first merely be-

cause of the greater simplicity and directness of his demonstration. We may now turn to a consideration of Pearson's more detailed results.

3. Pearson's Work

The material used by Pearson and his student, Miss Beeton, who worked with him on the problem, came from a number of different sources. Their first study dealt with three series from which all deaths recorded as due to accident were excluded. The first series included one thousand cases of the ages of fathers and sons at death, the latter being over 22.5 years of age, taken from Foster's "Peerage." The second series consisted of a thousand pairs of fathers and sons, the latter dying beyond the age of 20, taken from Burke's "Landed Gentry." The third series consisted of ages at death of one thousand pairs of brothers dying beyond the age of 20 taken from the "Peerage." It will be noted that all these series considered in this first study dealt only with inheritance in the male line. The reason for this was simply that in such books of record as the "Peerage" and "Landed Gentry" sufficiently exact account is not given of the deaths of female relatives. In a second study the material was taken from the pedigree records of members of the English Society of Friends, and from the Friends Provident Association. This material included data on inheritance of longevity in the female line and also provided data for deaths of infants, which were lacking in the earlier used material. The investigation was grounded upon that important branch of modern statistical calculus known as the method of correlation. For each pair of relatives between whom it was desired to study the intensity of inheritance of longevity a table of double entry was formed, like the one shown here as Table 4.

TABLE 4

Correlation table showing the correlation between father and son in respect of duration of life.

Duration of Life of Son	Duration of Life of Father																	
	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	98	103	Totals
23	1	1	2	5	3	11	6	7	11	9	6	12	8	2		2		86
28				1	6	4	5	12	15	10	13	10	7		1	1		85
33			1	2	2	5	7	8	7	10	7	8	8	4	1			70
38		1	1	2		2	8	5	3	9	11	11	9	5	2	1		70
43		1			1	5	1	5	6	11	10	10	17	5				72
48			1	1	2	5	5	4	6	9	12	15	5	3				68
53		1		3		5	7	3	2	11	11	14	10	1	1	1		70
58			1	3		4	5	10	8	10	5	8	9	3		2		68
63		2	1	3	5	1	4	8	13	9	11	11	11	5				84
68			1	6	3	6	7	5	5	6	14	16	12	7	2			90
73		1		2	1	6	5	4	7	9	10	14	13	8	8	1	1	90
78			1	1	2	2	4	4	4	10	5	8	9	4		3		57
83				1	1	5	3	1	2	3	7	10	13	3	2	2		53
88		1				2	3		1	4	7	5	1	2		2		28
93						1				2	2							5
98						1						1		1	1			4
Totals	1	8	9	30	26	65	70	76	90	122	131	153	132	53	18	15	1	1000

The figures in each cell or compartment of this table denote the frequency of occurrence of pairs of fathers and adult sons having respectively the durations of life indicated by the figures in the margins. Thus we see, examining the first line of the table, that there were 11 cases in which the average duration of life of the father was 48 years and that of the adult son 23 years. Farther down and to the right in the table there were 13 cases in which the average duration of life of the father and the son was in each case 83 years. These cases are mentioned merely as illustrations. The whole table is to be read in the same manner.

From such a table as this it is possible to calculate, by well-known mathematical methods, a single numerical constant of somewhat unique properties known as the coefficient of correlation, which measures the degree of association or mutual dependence of the two variables included in such double entry tables. This coefficient measures the amount of resemblance or association between characteristics of individuals or things. It is stated in the form of a decimal which may take any value between 0 and 1. As the correlation coefficient rises to 1 we approach a condition of absolute dependence of the variables one upon the other. As it falls to zero we approach a condition of absolute independence, where the one variable has no relation to the other in the amount or direction of its variation. The significance of a correlation coefficient is always to be judged, in any particular case, by the magnitude of a constant associated with it called the probable error. A correlation coefficient may be regarded as certainly significant when it has a value of 4 or more times that of its probable error, which is always stated after the coefficient with a combined plus and minus sign between the two. The coefficient is probably significant when it has a value of not less than 3 times its probable error. By "significant" in this connection is meant that the coefficient expresses true organic relationship and not merely a random chance result.

In Table 5 are the numerical results from the first study based upon the "Peerage" and "Landed Gentry."

TABLE 5

Inheritance of duration of life in male line. Data from "Peerage" and "Landed Gentry." (Beeton and Pearson).

Relatives		Correlation coefficient	Ratio of coefficient to its probable error.
x	y	r_{xy}	$r_{xy} \div E_r$
Father ("Peerage")	Son, 25 years and over	.115 ± .021	5.5
Father ("Landed Gentry")	Son, 20 years and over	.142 ± .021	6.8
Father ("Peerage")	Son, 52.5 years and over	.116 ± .023	5.0
Father ("Landed Gentry")	Son, 50 years and over	.113 ± .024	4.7
Brother (Peerage")	Brother	.260 ± .020	13.0

It is seen at once that all of the coefficients are significant in comparison with their probable errors. The last column of the table gives

the ratio of the coefficient to its probable error, and in the worst case the coefficient is 4.7 times its probable error. The odds against such a correlation having arisen from chance alone are about 655 to 1. Odds such as these may be certainly taken as demonstrating that the results represent true organic relationship and not mere chance. All of the other coefficients are certainly significant, having regard to their probable errors. Furthermore, they are all positive in sign, which implies that a variation in the direction of increased duration of life in one relative of the pair is associated with an increase in expectation of life in the other. It will be noted that the magnitude of the correlation between brother and brother is about twice as great as in the case of correlation of father with son. From this it is provisionally concluded that the intensity of the hereditary influence in respect of duration of life is greater in the fraternal relationship than in the parental. It evidently makes no difference, broadly speaking, so far as these two sets of material are concerned, whether there are included in the correlation table all adult sons, whatever their age, or only adult sons over 50 years of age. The coefficients in both cases are essentially of the same order of magnitude.

Perhaps some one will be inclined to believe that the correlation between father and son, and brother and brother, in respect of the duration of life arises as a result of similarity of the environments to which they are exposed. Pearson's comments on this point are penetrating, and I believe absolutely sound. He says:

> There may be some readers who will be inclined to consider that much of the correlation of duration of life between brothers is due to there being a likeness of their environment, and that thus each pair of brethren is linked together and differentiated from the general population. But it is difficult to believe that this really affects *adult* brothers or a father and his adult offspring. A man who dies between 40 and 80 can hardly be said to have an environment more like that of his brother or father, who died also at some such age, than like any other member of the general population. Of course, two brothers have usually a like environment in infancy, and their ages at death, even if they die adults, may be influenced by their rearing. But if this be true, we ought to find a high correlation in ages at death of brethren who die as minors. As a matter of fact this correlation for minor and minor is 40 to 50 per cent. less than in the case of adult and adult. It would thus seem that identity of environment is not the principal factor in the correlation between ages of death, for this correlation is far less in youth than in old age.

The results regarding minors to which Pearson refers are shown in Table 6. This table gives the results of the second study made by Beeton and Pearson on inheritance of duration of life, based upon the records of the Friends Societies. It appears in the upper half of the table that wherever a parent, father or mother, appears with a minor son or daughter the correlation coefficients are small in magnitude. In some cases they are just barely significant in comparison with their probable errors, as for example, the correlation of father and minor

TABLE 6

Inheritance of duration of life. Data from Quaker records. (Beeton and Pearson).

Relatives		Correlation coefficient	Ratio of coefficient to its probable error.
x	y	r_{xy}	$r_{xy} \div E_r$
Father	Adult son	0.135 ± .021	6.4
Father	Minor son	.087 ± .022	4.0
Father	Adult daughter	.130 ± .020	6.5
Father	Minor daughter	.052 ± .023	2.3
Mother	Adult son	.131 ± .019	6.9
Mother	Minor son	.076 ± .024	3.2
Mother	Adult daughter	.149 ± .020	7.5
Mother	Minor daughter	.138 ± .024	5.7
Elder adult brother	Younger adult brother	.229 ± .019	12.1
Adult brother	Adult brother	.285 ± .020	14.3
Minor brother	Minor brother	.103 ± .029	3.6
Adult brother	Minor brother	−.026 ± .025	1.0
Elder adult sister	Younger adult sister	.346 ± .018	19.2
Adult sister	Adult sister	.332 ± .019	17.5
Minor sister	Minor sister	.175 ± .031	5.6
Adult sister	Minor sister	−.026 ± .029	.9
Adult brother	Adult sister	.232 ± .015	15.5
Minor brother	Minor sister	.144 ± .025	5.8
Adult brother	Minor sister	−.006 ± .035	.2
Adult sister	Minor brother	−.027 ± .024	1.1

The cases above the horizontal line are all direct lineal inheritance; those below the line collateral inheritance.

son, and that of mother and minor daughter. In the other cases involving minors the coefficients are so small as to be insignificant. On the other hand, in every case of correlation between parent and *adult* offspring of either sex, the coefficient is 6 or more times its probable error, and must certainly be regarded as significant. It will further be noted that the magnitude of the coefficients obtained from these Quaker records is of the same general order as was seen in the previous table based on the "Peerage" and "Landed Gentry" material.

The lower part of the table gives the results for various fraternal relationships. In general the fraternal correlations are higher than the parental. The coefficients for minors or for minors with adults are very low and in most cases not significantly different from zero.. In four cases—namely, adult brother with minor brother; adult sister with minor sister; adult brother with minor sister; and adult sister with minor brother—the coefficients are all negative in sign, although in no one of the cases is the coefficient significant in comparison with its probable error. A minus sign before a correlation coefficient means that an increase in the value of one of the variables is associated with a decrease in the value of the other. So that these negative coefficients would mean, if they were significant, that the greater the age at death of an adult brother, the lower the age at death of his minor brother

or sister. But the coefficients are actually sensibly equal to zero. Pearson points out that the minus sign in the case of these correlations of adult with minor exhibits the effect of the inheritance of the mortality of youth. Minors dying from 16 to 20 are associated with adults dying from 21 to 25. That is, minors dying late correspond to adults dying early. This situation may be a peculiarity of the Quaker material with which this work deals. There is urgent need for further study of the inheritance of the duration of life on more and better material than any which has hitherto been used for the purpose. I have under way in my own laboratory at the present time an extensive investigation of this kind, in which there will be hundreds of thousands of pairs of relatives in the individual correlation tables instead of thousands, and all types of collateral kinship will be represented. Because of the magnitude of the investigation, however, it will be still a number of years before the results will be in hand for discussion.

The facts which have been presented leave no doubt as to the reality of the inheritance factor as a prime determinant of the length of the life span.

At the beginning it was pointed out that it was on *a priori* grounds highly probable that duration of life is influenced by both heredity and environment, and that the real problem is to measure the comparative effect of these two general sets of factors. We have seen that the intensity of inheritance of duration of life, taking averages, is of the order indicated by the following coefficients.

Parental correlation (adult children) $r=.1365$
Fraternal correlation (adults) $r=.2831$

Now we have to ask this question: What are the values of parental and fraternal correlation for characters but slightly if at all affected in their values by the environment? Happily, Pearson has provided such values in his extensive investigations on the inheritance of physical characters in man.

TABLE 7
Parental inheritance of physical characters in man. (*Pearson*).

Pair	Organ	Correlation
Father and Son	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.55
Father and Daughter	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.44
Mother and Son	Stature	.49
" " "	Span	.46
" " "	Forearm	.41
" " "	Eye Color	.48
Mother and Daughter	Stature	.51
" " "	Span	.45
" " "	Forearm	.42
" " "	Eye Color	.51

In Table 7 are given the values of the parental correlations for the four physical characters—stature, span, forearm length, and eye color. Now it is obvious that the differences of environmental forces impinging upon the various members of a homogeneous group of middle class English families (from which source the data for these correlations were drawn) can by no possibility be great enough to affect sensibly the stature, the arm-length, or the eye color of the adults of such families. It would be preposterous to assert that the resemblance between parents and offspring in respect of eye color is due solely, or even sensibly, to similarity of environment.

It is due to heredity and substantially nothing else. Now the average value of the 16 parental coefficients for the inheritance of physical characters shown in the table is

$$r = .4675$$

TABLE 8

Fraternal inheritance of physical characters in man. (Pearson).

Pair	Organ	Correlation
Brother and Brother	Stature	.51
" " "	Span	.55
" " "	Forearm	.49
" " "	Eye color	.52
" " "	Cephalic index	.49
" " "	Hair color	.59
Sister and Sister	Stature	.54
" " "	Span	.56
" " "	Forearm	.51
" " "	Eye color	.45
" " "	Cephalic index	.54
" " "	Hair color	.56
Brother and Sister	Stature	.55
" " "	Span	.53
" " "	Forearm	.44
" " "	Eye color	.46
" " "	Cephalic index	.43
" " "	Hair color	.56

Table 8 shows the coefficients for the fraternal inheritance of six physical characters, cephalic index (the ratio of head length and head breadth) and hair colour having been added to those given in the parental table. Again it is seen that the coefficients have all about the same values, and it is as apparent as before that the resemblance between brother and sister, for example, in eye-color, or arm length, or shape of head can not for a moment, because of the nature of the characters themselves, be supposed to have arisen because of the similarity of environment. The average value of all these fraternal coefficients is

$$r = .5156$$

From these data, with the help of a method due to Pearson, it is possible to determine the percentage of the death rate dependent upon the inherited constitution, and the percentage not so dependent. If

pN be the number of deaths in N cases which depend in no way upon the inherited constitution of the individual, then $(1\text{-}p)$ will represent the chance of an individual dying because of his inherited constitutional makeup, and $(1\text{-}p)^2$ will be the chance of a pair of individuals, say two brothers, both dying from causes determined by inheritance. If further r denotes the observed correlation between individuals in respect of duration of life, and r_o the correlation between the same kin in respect of such measured physical characters as those just discussed, in the determination of which it is agreed that environment can play only a small part, we have the following relation:

$$\frac{r}{r_o} = (1\text{-}p)^2$$

Substituting the ascertained values we have

1. From parental correlations.

$$0.1365 = .4675\ (1\text{-}p)^2$$
$$(1\text{-}p)^2 = .292$$
$$(1\text{-}p) = .54$$

2. From fraternal correlations

$$0.2831 = .5156\ (1\text{-}p)^2$$
$$(1\text{-}p) = .74$$

From these figures it may be concluded, and Pearson does so conclude, that from 50 to 75 per cent. of the general death rate within the group of the population on which the calculations are based, is determined fundamentally by factors of heredity and is not capable of essential modification or ameloriation by any sort of environmental action, however well intentioned, however costly, or however well advertised. *Mutatis mutandis* the same conclusion applies to the duration of life. I have preferred to state the conclusion in terms of death rates because of the bearing it has upon a great deal of the public health propaganda so loosely flung about. It need only be remembered that there is a perfectly definite functional relation between death rate and average duration of life in an approximately stable population group, expressible by an equation, in order to see that any conclusion as to the relative influence of heredity and environment upon the general death rate must apply with equal force to the duration of life.

4. The Selective Death Rate in Man

If the duration of life were inherited it would logically be expected that some portion of the death rate must be selective in character. For inheritance of duration of life can only mean that when a person dies is in part determined by that individual's biological constitution or makeup. And equally it is obvious that individuals of weak and unsound constitution must, on the average, die earlier than those of strong, sound, and vigorous constitution. Whence it follows that the chances of leaving offspring will be greater for those of sound constitution

than for the weaklings. The mathematical discussion which has just been given indicates that from one-half to three-fourths of the death rate is selective in character, because that proportion is determined by hereditary factors. Just in proportion as heredity determines the death rate, so is the death rate selective. The reality of the fact of a selective death rate in man can be very easily shown graphically.

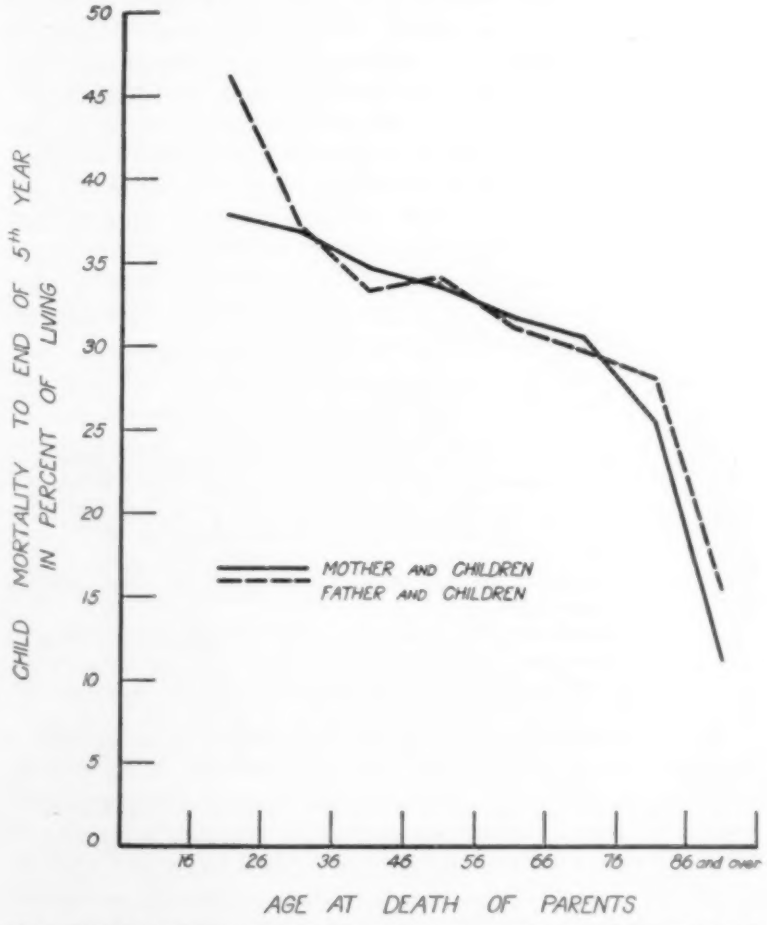

FIG. 4. DIAGRAM SHOWING THE INFLUENCE OF AGE AT DEATH, PARENTS UPON THE PERCENTAGE OF OFFSPRING DYING UNDER 5 YEARS. (After Ploetz)

In Fig. 4 are seen the graphs of some data from European royal families, where no neglect of children, degrading environmental conditions, or economic want can have influenced the results. These data were compiled by the well-known German eugenist, the late Professor Ploetz of Munich. The lines show the falling percentage of the infantile death rate as the duration of life of the father and mother in-

creases. Among the children of short-lived fathers and mothers, at the left end of each line, is found the highest infant mortality, while among the offspring of long-lived parents the lowest infant mortality occurs, as shown at the righthand end of the diagram.

The results so far presented regarding a selective death rate and inheritance of duration of life, have come from selected classes; the aristocracy, royalty or Quakers. None of these classes can be fairly said to represent the general population. Can the conclusion be transferred safely from the classes to the masses? To the determination of this point one of Pearson's students, Dr. E. C. Snow, addressed himself. The method which he used was, from the necessities of the case, a much more complicated and indirect one than that of Pearson and Ploetz. Its essential idea was to see whether infant deaths weeded out the unfit and left as survivors the stronger and more resistant. All the infants born in a single year were taken as a cohort and the deaths occurring in this cohort in successive years were followed through. Resort was had to the method of partial or net correlation. The variables correlated in the case of the Prussian data were these:

1. x_0 = Births in year a given cohort started.
2. x_1 = Deaths in the first two years of life.
3. x_2 = Deaths in the next eight years of life.
4. x_3 = Deaths in the ten years of all individuals not included in the particular cohort whose deaths are being followed.

In the case of the English data the variables were:

x_0 = Births in specified year.
x_1 = Deaths in the first three years of life of those born in specified year.
x_2 = Deaths in fourth and fifth years of life of those born in specified year.
x_3 = The "remaining" deaths under 5.

The underlying idea was to get the partial or net correlation between x_1 and x_2, while x_0 and x_3 are held constant. If the mortality of infancy is selective, its amount should be negatively correlated to a significant degree with the mortality of the next eight years when the births in each district considered are made constant and when the general health environment is made constant. Under the constant conditions specified a negative correlation denotes that the heavier the infantile death rate in a cohort of births the lighter will be the death rate of later years, and *vice versa*. The last variable, x_3, is the one chosen, after careful consideration and many trials, to measure variation in the health environment. If any year is a particularly unhealthy one—an epidemic year for example—then this unhealthiness should be accurately reflected in the deaths of those members of the population not included in the cohort under review.

Snow's results for English and Prussian rural districts are set forth

TABLE 9

Snow's results on selective death rate in man. English and Prussian rural districts.

Data			Actual correlation $r_{12\cdot03}$	Expected correlation if no selection
Males:				
	English Rural Districts	(1870)	−0.4483	−0.0828
		(1871)	− .3574	− .1014
		(1872)	− .2271	− .0807
	Prussian Rural Districts	(1881)	− .9278	− .0958
		(1882)	− .6050	− .0765
Females:				
	English Rural Districts	(1870)	− .4666	− .0708
		(1871)	− .2857	− .0505
		(1872)	− .5089	− .0496
	Prussian Rural Districts	(1881)	− .8483	− .0933
		(1882)	− .6078	− .0705

in Table 9. From this table it is seen that in every case the correlations are *negative*, and therefore indicate that the mortality of early life is selective. Furthermore, the demonstration of this fact is completed by showing that the observed coefficients are from 3 to 10 times as great as they would be if there were no selective character to the death rate. The coefficients for the Prussian population, it will be noted, are of a distinctly higher order of magnitude than those for the English population. This divergence is probably due chiefly to differences in the quality of the fundamental statistical material in the two cases. The Prussian material is free from certain defects inherent in the English data, which cannot be entirely got rid of. The difference in the coefficients for the two successive Prussian cohorts represents, in Snow's opinion, probably a real fluctuation in the intensity of natural selection in the one group as compared with the other. How significant Snow's results are is shown graphically in Figure 5.

Snow's own comments on his results are significant. He says:

> The investigations of this memoir have been long and laborious, and the difficulties presented by the data have been great. Still, the general result cannot be questioned. *Natural selection, in the form of a selective death-rate, is strongly operative in man in the early years of life.* Those data which we believe to be the best among those we have used—the Prussian figures—show very high negative correlation between the deaths in the first two years of life and those in the next eight, when allowance is made for difference in environment. We assert with great confidence that a high mortality in infancy (the first two years of life) is followed by a corresponding low mortality in childhood, and conversely. The English figures do not allow such a comprehensive survey to be undertaken, but, so far as they go they point in the same direction as the Prussian ones. The migratory tendencies in urban districts militate against the detection of selective influences there, but we express the belief that those influences are just as prevalent in industrial

as in rural communities, and could be measured by other means if the data were forthcoming.

Our investigation substantiates for a general population the results found by Pearson and Ploetz for more restricted populations, and disagrees with many statements of health officers. It is with great reluctance that we point out this disagreement, and assert a doctrine which, in the present sentiment of society, is bound to be unpopular. We have no feelings of antagonism towards the efforts which have been made in recent years to save infant life, but we think that the probable consequences of such actions, so far as past experience can indicate them, should be completely understood. All attempts at the reduction of mortality of infancy and childhood should be made in the full knowledge of the facts of heredity. Everybody knows the extreme differences in constitutional fitness which exist in men and women. Few intelligent people can be ignorant of the fact that this constitutional fitness is inherited according to laws which are fairly definitely known. At the same time marriage is just as prevalent among those of weak stocks as

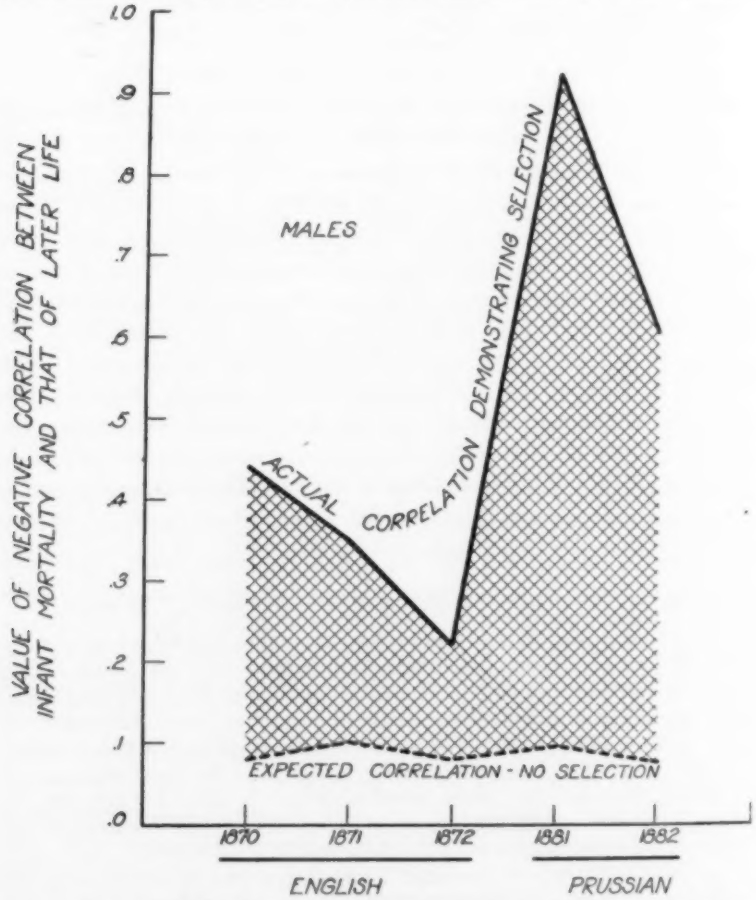

FIG. 3. SNOW'S RESULTS ON SELECTIVE DEATH RATE IN MAN. The cross-hatched area may be taken, in comparison with the small clear area at the bottom, to measure the influence of the selective death rate in increasing the correlations

among those of the vigorous, while the fertility of the former is certainly not less than that of the latter. Thus a proportion of the infants born every year must inevitably belong to the class referred to in the report as "weaklings," and, with Pearson's results before us, we are quite convinced that true infantile mortality (as distinct from the mortality due to accident, neglect, etc.—no small proportion of the whole) finds most victims from among this class. Incidentally we would here suggest that no investigation into the causes of infant and child mortality is complete until particulars are gathered by the medical officers of the constitutional tendencies and physical characters of the parents.

Our work has led us to the conclusion that infant mortality *does* effect a "weeding out" of the unfit; but, though we would give this conclusion all due emphasis, we do not wish to assert that any effort, however small, to the end of reducing this mortality is undesirable. Nobody would suggest that the difference between the infant rates in Oxfordshire and Glamorganshire (73 and 154 per 1,000 births respectively, in 1908) was wholly due to the constitutional superiority of the inhabitants of the former county. The "weeding-out" process is not uniform. In the mining districts of South Wales, accident, negligence, ignorance and unsanitary surroundings account for much. By causing improvements under these heads it may be possible to reduce the infant mortality of Glamorganshire by the survival of many who are not more unfit than are those who survive in Oxfordshire, and the social instincts of the community insist that this should be done.

This work of Snow's aroused great interest, and soon after its appearance was controverted, as it seems to me quite unsuccessfully, by Brownlee, Saleeby and others.

Happily the results of Pearson, Ploetz and Snow on the selective death rate have recently been accorded a confirmation and extension to still another group of people—the Dutch—in some as yet unpublished investigations carried out by Dr. F. S. Crum of the Prudential Life Insurance Company, with the assistance of the distinguished mathematical statistician, Mr. Arne Fisher. By the kind permission of these gentlemen I am able to state the general results of these investigations in advance of their publication.

The Dutch Government publishes annually data which undoubtedly furnish the best available material now existing in the world for the purpose of determining whether or not there is a positive or negative correlation between infant mortality and the mortality in the immediately subsequent years of life. Fisher's mathematical analysis embraces a very large body of material, including nearly a million and a half births, and nearly a quarter of a million deaths of males occurring in the first five years of life. The Holland data make it possible to develop life tables for every cohort of births and this has been done in the 16 cohorts of males during the years 1901-1916. The data also make it possible to work up these life tables for urban areas and for rural areas. After carefully eliminating secular disturbances the Holland material appears to prove quite conclusively for the rural districts that there is a definite negative correlation, of significant

magnitude, between infant mortality and the mortality in the immediately subsequent years of life. The only place where positive correlation appears is in the four large cities of the country with more than a hundred thousand inhabitants each. Fisher makes the following point (in a letter to the present writer) in explanation of these positive correlations. He says:

> The larger cities are better equipped with hospital and clinical facilities than the smaller cities and the rural districts. More money is also spent on child welfare. Is it therefore not possible that many feeble lives who in the course of natural circumstances would have died in the first year of life are carried over into the second year of life by means of medical skill? But medicine cannot always surpass nature, and it might indeed be possible that among cohorts with a low mortality during the first two years of life there will be an increase of death rate in the following three years of life.

Altogether, we may regard the weight of present evidence as altogether preponderant in favor of the view *that the death rate of the earliest period of life is selective—eliminating the weak and leaving the strong*. From our present point of view it adds another broad class of evidential material to the proof of the proposition that inheritance is one of the strongest elements, if not indeed the dominating factor, in determining the duration of life of human beings.

VITAMINS AND FOOD DEFICIENCY DISEASES

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AMERICAN scientific men have been credited with lagging behind the progress shown in England and Europe in the domain of medicine. Surgery has come fully into its own, in the western hemisphere. But American medicine too often is held to be engaged solely in practising and teaching, and all too little in investigating. Its contributions to scientific knowledge are held to be meager and unimportant. Among many, one of the finest refutations of this mistaken notion is discovered in the impetus given by American scientists to our understanding of dietetics and food values, and the use of diet in the prevention and cure of disease. Strictly speaking, modern medicine has relatively little to do with drugs. Webster's definition of medicine is best, namely, the prevention, cure and alleviation of disease.

It has remained for American investigators to lead in showing how important is the rôle assumed by diet in the prevention, cure and alleviation of disease. The old dictum, "Feed a cold and starve a fever" has been reversed. Laboratory studies on the basis of exact measurements of energy requirements in the body under normal and pathologic conditions, have demonstrated that in the presence of fever, more energy is required, and that, if this additional energy is not furnished in an increased diet, it will be secured at the expense of serious inroads on the body reserves, and that such inroads result in definite symptoms and in abnormal physiologic processes which invariably tend to make the invading disease more dangerous.

Our appreciation of dietary requirements for health has advanced so that the term, a balanced diet, means considerably more than merely the provision of a sufficient energy supply. "Man shall not live by bread alone" is equally true of his physiologic mechanism. To-day a balanced diet implies of course that the body shall receive a sufficient quantity of energy from the food, that there shall be a proper number of calories of food energy per unit of body weight. It means a suitable distribution of this total caloric requirement between carbohydrate, fat and protein. It means also a proper mineral supply of inorganic salts. Water is a prime necessity for digestion, absorption and for cellular function. Four-fifths of the body weight is water and only one-tenth of the water in the body is found in the blood. Hence the necessity for sufficient water intake.

Since the epochal work of Emil Fischer, we now understand something still further of the mysteries of protein or nitrogenous metabolism. In food the protein molecule is extremely large and complex. In the process of digestion, through the action of digestive juices and enzymes, this molecule is broken down into relatively small units called amino acids. In digestion all forms of protein yield these ultimate amino acids or building stones. Less than a score of amino acids are known, but all proteins are composed of various groupings of two or more of these building stones. Thus it is easily understood that for repair of body tissue and for growth, there must be a correct selection of amino acids. No protein contains all the amino acids and many proteins lack certain amino acids which are absolutely essential for growth or for maintenance of body cells. Thus in practical dietetics it is necessary to do more than secure merely a certain total quantity of protein per day. That protein must be so selected, in quantity and quality, as to supply the required amino acids or ultimate building stones in correct variety and quantity. This explains why proteins of cereal or vegetable origin may not entirely substitute with safety for proteins of animal origin.

For some time it was supposed that nutrition consisted solely in the absorption and utilization by the body, either for energy or for tissue building, of food stuffs which, according to the preceding description, had been adequately prepared through the medium of digestion. These food stuffs seemed to have been placed on a level of chemical and mechanical exactitude by the wonderful development of physiological chemistry to which reference has been made, and by the classification of food into the great divisions of proteins (amino acids), fats, carbohydrates, minerals and water. The rapidly advancing and changing conception of food deficiency diseases has, however, led to and accompanied an extension of the classification of food elements to include certain as yet largely unknown substances, called vitamins, which have a definite controlling influence on nutrition, health and growth. Imbalance, or lack of some or all of this group, is believed to eventuate in physiological perversions which proceed to clinical disease. This conception parallels the idea of physiologic perversions due to deficiency in the earlier recognized food elements, as observed in starvation, or in the results of the body's inability to burn carbo-hydrate in diabetes.

In general food deficiency may be said to act in one of three ways to produce a departure from normal health and nutrition. It may result simply in mal-nutrition, or better, poor nutrition, from insufficient supply of the particular food elements lacking. This form of mal-nutrition is automatically more or less compensated for by increased utilization of other food elements. Such a compensatory use of other food elements occurs least in the case of protein insufficiency. Proteins may be

spared in bodily nutrition by increased utilization of carbo-hydrate and fat, and thus the minimum necessary intake of nitrogenous food may be lowered, but no other food can actually and entirely replace the function of protein.

In the second place, a deficiency of some food element may cause a general disturbance of metabolism. This is illustrated by the condition of acid intoxication, or acidosis, which may result from a diet excessive in fat and deficient in carbo-hydrate, as seen, for instance in certain types of infantile acidosis, and in the dangerous and often fatal acidosis of diabetes. In the third place, a food deficiency may predispose to secondary factors which are directly responsible for disease. Thus a condition of under-nourishment from general deficiency or starvation, predisposes to infection. Again deficiency of a particular food element may result in a selective mal-nutrition of some organ or system of the body, as illustrated in the nerve degenerations of beriberi.

Thus it is evident that the problem of food deficiency is no simple one, but that it is complicated by selective results produced in the organism, by secondary factors which may become operative in the presence of the deficiency, and by obscure inter-relations and balances of nutritive equilibrium which easily may be disturbed by a variation in the component food elements. Here too must be considered the activity of various physiologic factors of safety in the animal body, which nature providently furnishes as additional safeguards against disruption of the delicate and sensitive adjustment necessary for health. Such a factor of safety is seen in the mechanism involved in maintaining proper alkalinity of the blood serum, thus preventing acidosis. Another illustration is the detoxifying function of the liver whereby various chemical poisons, if they happen to gain access to the blood stream, are automatically neutralized.

Given, then, a dietary constructed with due regard for water, mineral salts, carbo-hydrate, fat and protein building stones, one additional fact must yet be taken into account to secure a perfectly balanced food supply. This final factor has reference to the protein-like substances called vitamins, or accessory food substances. At present three types of these substances are recognized and a proper proportion of each is required to prevent serious derangement of the metabolism. It is not known whether these substances act in the body in a definite constructive fashion, entering themselves into the chemistry of metabolic processes, whether they act as catalytes, stimulating and originating changes in other substances but taking no chemical part themselves.

Two general lines of investigation are responsible for our present knowledge of vitamins. For a considerable time these two lines seemed contradictory, but they have gradually converged and afforded perspective and unity to our entire conception. The name "vitamin" was coined in 1911 by Casimir Funk for a substance occurring in rice

polishings and yeast, which appeared to cure neuritis in birds and beriberi in man. This line of investigation was based on the earlier work of Eijkman in the Dutch East Indies, who, in 1897, had demonstrated a multiple neuritis in fowls fed on a polished rice diet and observed that this neuritis was curable by feeding rice polishings. In 1907, Fraser and Stanton, American workers in the Philippines, found that an alcoholic extract of rice polishings would cure experimental neuritis. Funk found the same to be true for yeast and from an imperfect knowledge of the chemistry of the substance, called it vitamin, an amino or basic nitrogenous body necessary for normal life. Thus the study of beriberi led to the name and conception of vitamins. Hopkins has suggested "accessory food substances" as a better term, and Graham Lusk "food hormones." Both suggestions have merit and the word vitamin has definite disadvantages, but priority, common usage and brevity have established vitamin as the term of choice and so it doubtless will remain.

The second line of investigation developed on the basis of nutritional studies by McCollum and his associates, by Osborne and Mendel, and others, which showed that various foods of approximately similar caloric value and total content of fat, carbo-hydrate and protein, exhibited an enormous variation in their ability to maintain life and promote growth. These experiments, in huge numbers, were carried out on animals and the results threw brilliant light on the problems of the food deficiency diseases as observed clinically in human-kind. It was found that certain food stuffs produced results in growth and nutrition out of all proportion to their quantitative or caloric value. Out of a great mass of carefully directed investigation, there crystallized in 1915 the recognition of two groups of vitamins, named by McCollum "fat soluble A" and "water soluble B." More recently evidence has accumulated in favor of a third group of vitamins called "water soluble C." This C group has to do with the prevention of scurvy. It is now possible by specialized chemical procedures to concentrate and isolate vitamins of these three groups.

The exact chemical nature of vitamins is unknown. The exact relation of vitamin deficiency is not in all cases clear. We can say, however, that growth, beriberi and xerophthalmia are directly related to A and B factors. Scurvy seems definitely connected with deficiency of the C vitamin. Evidence has accumulated that pellagra belongs with the vitamin deficiencies, and then follow a number of less clearly defined conditions, such as rickets, various forms of infantile and adult mal-nutrition, anemia and marasmus. These latter seem to be associated with an excess of carbo-hydrate in the diet, together with an insufficiency of mineral and animal constituents. While many cases of eczema now are known to be caused by a skin reaction to certain specific proteins of the food, still a large percentage of eczema depends

on or is greatly influenced by an excess of fat or carbo-hydrate. The last statement applies also to acne or "pimples". A certain form of acid poisoning in babies is caused by excess fat in the diet. To a great degree dietary irregularities are responsible for the uric acid abnormalities of gout, and finally no small proportion of cases of constipation follow a diet lacking in bulk or in cellulose.

Again, as has been mentioned, symptoms which had been ascribed to certain diseases are found to be due in all probability to defective nutrition, again illustrating the relation of food deficiency to disease production. For example, diarrhea, delirium and the so-called typhoid state have been considered integral elements of the natural history of typhoid fever. However, since the introduction of the high calory diet in typhoid, these symptoms are usually mild or in abeyance. The inference is justifiable that these symptoms are due, not to the typhoid infection, but to a food deficiency resulting in mal-nutrition. This deficiency is doubtless qualitative as well as quantitative. It will be found probably that many symptoms of many diseases are not at all pathognomonic of those diseases, but are characteristic of and common to some form of unbalanced diet.

There is good reason to believe that the primary cause for the onset of many diseases will be found eventually to lie with a dietetic deficiency of some sort. In the case of amebic dysentery, for instance, McCarrison in Coonoor, India, found experimentally on monkeys that the disease appeared in the presence of a food deficiency where it did not develop when the monkeys were well nourished on a balanced diet. There is sound judgment in McCarrison's conclusion "emphasizing the importance in practice of a study of the dietary history of the case, believing as I now do that bacterial agencies are often but weeds which flourish in soil made ready for them by dietary defects, and believing also that in the fuller comprehension of the science of dietetics we shall understand more perfectly the beginning of disease and its therapy."

One further illustration of the vast importance of food deficiency in social, economic and health welfare, lies in the situation stressed by Dr. Mazyck P. Ravenel, president of the American Public Health Association. Dr. Ravenel advocates the cultivation of a wholesome fear of those diseases and infections which, while not apt to result in death, yet are attended by a high degree of social inefficiency and invalidism. Less emphasis on mortality and more emphasis on invalidism figures gives a better estimate of the real human seriousness of disease. Malaria destroyed Greece and Rome, and malaria has not a high death rate. Influenza struck the world with shocking severity, but it left no social scar on the race, no aftermath of invalidism and social inefficiency. Chronic exhaustive diseases like malaria, hookworm, tubercu-

losis and syphilis are, after all, the greatest scourges of mankind, and their social and economic cost is highest.

In two ways food deficiency is closely related to the considerations detailed in the last paragraph. In the first place, the greatest single predisposing factor to the development of the chronic exhaustive type of disease is food deficiency and mal-nutrition. Secondly, just as in the case of specific diseases, the more serious human losses are due to invalidism and social inefficiency, so in the realm of nutrition, after all is said, the loss from the definite specific deficiency diseases does not bulk so great as the huge loss from vague ill-health and more or less severe invalidism resulting from unbalanced or insufficient diet. In this connection are to be noted the nutritional dangers attendant on the increasing use of food substitutes. Examples of such substitutes are cotton seed oil for olive oil, or cod liver oil, margarines for butter, and the use of milk powders. Food substitutes are very important and may be very dangerous on a broad scale. The tendency in America is to excessive utilization of meats and sweets, with a subnormal employment of vegetables, fruits and dairy products. Such racial, local or individual aberrations of diet are vastly important and to an unbelievable degree are concerned with a sub-normal status socially, economically and in health. From such a sketchy survey it is evident that the science of dietetics promises to become ever more important in the treatment and prevention of disease, and as essential from the sanitary and public health point of view as for the individual man or woman.

We turn now to that smaller group of diseases which have been noted as having a direct relation to vitamin deficiency. While we can not state with absolute accuracy the specific element lacking in each case, we can assert with complete safety that they are due to an unbalanced or faulty diet, and that certain dietary procedures will serve adequately to prevent and to cure them.

Having clearly in mind what is meant by the term vitamin, and in spite of the disadvantages of the name, using it in a generic sense, it is next in order to consider why there should be clinical differences in disease types arising from a common etiology. Why should a vitamin deficiency in one case eventuate in beriberi, in another in pellagra and in a third in scurvy? While this question can not be fully answered at present, certain suggestive hypotheses may be predicated. As already explained, there is ground for the belief that vitamins are not unit substances, but represent a group chemically related and unstable, which may well have certain inter-relations necessary for their physiologic functioning. Thus absence of one type might be associated with a special clinical syndrome.

Recalling the three methods in which food deficiency may disturb the nutritional status, it is apparent that a vitamin deficiency may also produce differing clinical results by virtue of secondary factors which

may become operative under varying conditions of climate, general condition of patient, concurrent infection, age—in short, that the effect of the vitamin deficiency may be influenced or even determined by all manner of extraneous circumstances, whose operation may conceivably be initiated or modified by the deficiency. It is not unlikely that the general type of caloric food supply used may be of importance, since we find for instance that beriberi is most common in rice eaters, and that pellagra is usually associated with maize.

Before discussing the common pathologic features of the deficiency diseases and methods of cure and prevention, it may be well to rehearse briefly the clinical picture of scurvy, beriberi and pellagra, with some suggestions of the experimental basis for believing them due to a food deficiency.

Scurvy

Armies and ships have suffered notoriously from scurvy. The name suggests the days of early exploration, long voyages and sailing ships. Whalers, fishermen, armies, sailors, explorers—all have feared and fought scurvy. As will be seen, the very circumstances which now are best explained as due to a food deficiency, were once considered conclusive proof of the disease being an infection and this view has prevailed to some extent, as in Russia, for example, almost to the present time. Its true nature was apprehended by the British much earlier as witnessed by the virtual disappearance of scurvy in the British navy since the regular rationing of lime juice began in 1795.

Scurvy is characterized by a pronounced inclination to hemorrhage, with soft, spongy bleeding gums, and hemorrhage under the skin and from mucus membranes. Certain bony changes follow and a condition of progressive weakness and anemia. In children, hemorrhages are more apt to occur under the periosteum causing what is often diagnosed by the mother as "rheumatism of the legs", and characteristic skeletal changes are seen. The condition rapidly improves upon the addition of anti-scorbutic articles to the diet. Fresh meat and vegetables, especially with limes, lemons, onions, etc., are quickly curative except in the extreme stage.

Comrie has recently detailed his experiences while on duty with British troops in northern Russia in 1919. Scurvy appeared on a large scale among prisoners and natives. After several months on a diet deficient in protein, vegetables and fresh foods, the disease appeared in wholesale fashion. Its effects were doubtless intensified by the crowded prisons, general poor surroundings, and the long Arctic night. A purpuric rash on the legs usually came first, accompanied by mental depression, loss of energy and weakness. Bleeding gums, swollen ankles, and hemmorrhages into muscles and joints rapidly followed. Pain was noticeably present. Recovery was rapid with correction of the diet

alone, and in a month's time the victims showed few sequels of the disease. An effective anti-scorbutic was found in germinated peas or beans. Preserved lime juice was useless.

Another striking outbreak of scorbutic disease occurred as reported by Siccardi, in Italian troops serving at high altitudes in the Alps. In the summer of 1916 these troops suffered from a transient epidemic of a hemorrhagic form of scurvy. These hemorrhages were noted among those sick of other diseases as well as in men who had no other complaint. The disease was traced to an unbalanced diet, in the presence of cold, and ill ventilated under-ground quarters, and it was easily controlled by proper diet and rest.

Infantile scurvy is of surprising frequency especially in cities, where the widespread use of Pasteurized milk always brings danger of scurvy unless corrected by anti-scorbutics. Infantile scurvy is not common in the advanced stage characterized by very poor nutrition, "rheumatism of the legs," and bleeding spongy gums. But of surprising frequency, especially in cities, is a status of more or less indistinct symptoms associated with failure to gain weight and a tendency to hemorrhage, especially beneath the skin and mucus membranes, irritability and fretfulness, and sometimes femoral tenderness. Pateurized milk should be corrected by the addition to the diet of orange juice. It must be remembered that the advantage of Pasteurization vastly overbalances its tendency to produce scurvy, and that this tendency is easily controlled by a simple means.

In the group of deficiency diseases mid-way between scurvy and beriberi should be mentioned a peculiar syndrome called "ship beriberi." This affection differs from beriberi in its lack of involvement of the peripheral nervous system and is related to scurvy by its tendency to hemorrhage. The Newfoundland fishermen suffer from a similar condition in which a beriberi-like dropsy is associated with sore, bleeding gums. On the Labrador, the Esquimaux are frequently victims of scurvy and beriberi.

Dr. John M. Little, writing from Newfoundland, has described a deficiency disease related in causation and also doubtless in pathology, to this group. It is known among the natives as kallak. Commenting on the need for proper vitamin content in the diet, Dr. Little states that it is largely unknown as to where the Esquimaux get the necessary ingredients for a balanced diet outside of meat. The meat supply comes from seals, caribou, birds and fish. In good seasons berries too, are abundant, and when frozen, keep well. Dr. Little points out a possible source of carbo-hydrate supply when either civilized foods are not to be had, or when there is a failure of the berry crop. He says that the great feast of the Esquimaux consists of a thick soup made of the blood and stomach contents of the caribou. The caribou

eats coarse vegetable matter such as lichens, moss, tree bark and small twigs, leaves and shoots, which are entirely unsuitable for the human stomach. The powerful digestive juices of the animal's stomach convert this coarse vegetable mass into forms which in turn can be acted upon by the more delicate digestive mechanism of man, and thus rendered assimilable. Thus is there secured the requisite vitamin supply from fresh vegetable sources.

Kallak appears on the Labrador in endemic form when there is a deficiency especially of seal meat and berries, resulting probably in a deficiency of the fat-soluble type of vitamins. It is in turn prevented and cured by an abundance of seal meat and berries. It shows itself in successive crops of a pustular erruption with intense itching. The disease tends to recovery as soon as a balanced diet is procured. Dr. Darling has described another variant of scurvy in the South African Rand, which has certain features approximating beriberi.

Beriberi

Beriberi is a disease of antiquity known and described in ancient China, and recorded as having attacked a Roman Army in Arabia before the Christian era. It is pre-eminently a disease of the Orient and Pacific islands, although now widespread in Africa and South America, and not infrequently reported from other countries. It is not unknown in San Francisco and other parts of the United States. Its common association with a predominant rice diet does not always hold true. An instance of this is afforded by Draper, who in 1916 recounted nine early cases in a crew of fourteen men on a Norwegian bark touching at St. Helena. Here the victims had eaten sparingly of rice and had an abundance of fresh vegetables. An evidently beriberic diet was not demonstrable. Such instances lend credence to the parasitic theory of causation, held especially by certain English writers. For example, one of the most competent sanitarians in the Far East, Dr. Arthur Stanley, health officer of Shanghai, wrote in his 1914 report, "The cause of this disease (beriberi) remains under close observation, though up to the present wrapped in obscurity. The evidence preponderates in favor of the disease being an infectious one, having no direct relation to food but infective through body vermin." This view, however, is not tenable in relation to the American and Dutch results in the Philippines and East Indies.

Beriberi can now be classified accurately as a food deficiency disease caused by a lack of neuritis-preventing vitamin, water soluble B, in the food. Its occurrence in rice-eaters is associated with the use of polished rice, where the pericarp is removed from the grain. In this pericarp is the vitamin. The pericarp also contains an important fraction of phosphorus and the relative quantity of vitamin present can be measured by the quantity of phosphorus. Less than 0.4 per

cent. of phosphorus pentoxide indicates a dangerous vitamin deficiency, if rice is the chief article of diet.

Beriberi is essentially a disease of the nervous system and shows itself in poly-neuritis, accompanied by an edema especially of the lower extremities and a weakened heart. This last is an important differential point, and the extreme tendency to cardiac failure is most serious. The disease may be acute and fatal within a few days or it may pursue a chronic course. The term beriberi, includes a large and more or less ill-defined group of diseases which have not yet been carefully separated. There are various types and all degrees of intensity, now one and now another symptom outstanding. Many forms are on the borderline of scurvy and may represent a combined deficiency. If the neuritis and nerve damage are sufficiently extensive, there may be a residual paralysis which long outlasts the original disease. Beriberi is often of importance in its incipient or larval form, because it predisposes to other diseases and in turn, larval beriberi may suddenly fulminate under the excitation of some other acute disorder. Thus beriberi is remarkably frequent in association with acute dysentery. It is interesting to note that beriberi is almost unique among tropical diseases in having no features of laboratory importance. The diagnosis rests solely on clinical data and the laboratory findings are entirely negative or normal.

Pellagra

Pellagra is an endemic disease of modern history. It is not definitely known to have been recognized earlier than the 18th century, when it was described in Italy and Spain as of rather wide distribution. From the first reports in Italy it has been ascribed to a maize dietary. It was early identified with "Alpine scurvy". The disease was recognized in Egypt in the first half of the nineteenth century, and since then in France and other parts of Europe. It was first described in the United States in 1907 but had undoubtedly existed there for an indefinite time preceding. It is estimated that there are 125,000 cases in the United States at present. According to Goldberger of the U. S. Public Health Service, who, with his associates has studied the disease exhaustively, it is one of the foremost causes of death in the southern states, in 1916 ranking fourth in Mississippi, third in Alabama, second in South Carolina. Not only this, but it is responsible for an unguessed total of sickness and physical inefficiency in addition. Its actual death rate is about 5 per cent. The relative infrequency of pellagra outside the endemic area in the United States will probably be found related to the dietary deficiency which we believe is its cause.

The incidence of pellagra has a close relationship to economic circumstances and living conditions. High food costs and hard times lead to poor sanitary and unhygienic living conditions, which as al-

ways, reach their climax where housing and sanitary knowledge are meager. This tends to enforce a dietary favorable to the development of pellagra especially in the south where corn, fat pork and certain types of vegetable food, are associated with a dearth of lean fresh meat, milk, eggs and green fresh vegetables. Following the economic conditions of 1914, the incidence of pellagra rose in 1915, again to decline as conditions improved a year later. Again in 1917 an increase was observed, due to like causes, and accurately foretold by the scientists of the Public Health Service.

The symptoms of pellagra are in three groups, appearing respectively in the skin, gastro-intestinal tract and nervous system. Pellagra, or "rough skin," derives its name from an early observation of the skin. Roughened, dry patches of erythema, often superficially similar to sunburn, and symmetrically located, are the characteristic lesions. These areas usually are on surfaces exposed to the sun, but not necessarily so. The second major group of symptoms arises from the gastro-intestinal tract, and includes various forms of indigestion, diarrhea, increased acidity of the stomach, and sore mouth. The mouth condition, in fact, is suggestive of sprue. Again, the tender bleeding gums are suspicious of scurvy, and represent a relationship to that disease as well as explaining the old name of "Alpine scurvy". The third major group of symptoms is referable to the nervous system. Fortunately not all cases of pellagra progress to insanity. But from the first a neurasthenic condition is present to which are added gradually various paresthesias, changes in reflexes, suicidal attempts, tremors, and, in the final stages, a confusional insanity.

All of these symptoms show a remarkable vernal periodicity, advancing in the springtime and receding toward autumn and winter. Not infrequently for several years the only symptoms noted will appear in the spring and not be related to each other by the patient. Fever is not present typically, except late in the disease and probably represents intercurrent infection due to the weakened organism. The outlook in pellagra is very dark unless the patient can be subjected to proper dietary treatment. Under such proper conditions, improvement and cure ensue even in advanced cases. Treatment cannot repair, of course, broken down tissues or remove organic changes in the brain and elsewhere.

Other Deficiency Diseases

As has been pointed out, there is a heterogeneous group of diseases and overlapping clinical conditions caused by deficiency of vitamin supply. One of the most definite of these is xerophthalmia, in which failing vision and blindness are produced by increasing opacity of the cornea. H. Gideon Wells has described the occurrence of xerophthalmia on a large scale among the famine sufferers of Roumania

where it was promptly relieved by the administration of cod liver oil. The malady is evidently due to deficiency of the fat soluble A vitamin. Another and perhaps less clearly defined disorder is war edema, war dropsy, famine edema, or perhaps best, in the words of Wells, "nutritional dropsy". It was observed on a huge scale among prisoners of war in Germany and rather in those who were compelled to work while undernourished than among those who were merely underfed. Decreased protein and caloric intake are associated. It was frequently seen in conjunction with xerophthalmia. Another affection, similar in some points to beriberi and again to war edema, was reported from northern Africa during the Great War. This nutritional edema is probably identical with the dropsy occurring in infants fed for long periods on a highly carbonaceous diet.

It has been suggested that, succeeding an obvious state of mal-nutrition in infantile life, there may appear some disorder in later life with no apparent relation to the causal mal-nutrition. As an example of this, indications are cited that dental caries is produced by a deficiency in early life of a vitamin similar to fat soluble A. More recently most interesting experiments have been conducted by W. G. Karr, who finds a striking relation between the presence of water soluble B vitamin and appetite. This appetite-provoking vitamin is found in abundance in tomatoes and brewers' yeast.

Comparative Pathology

The beriberi-scurvy group of deficiency diseases exhibit a striking relationship in morbid anatomy. Darling working in the Canal Zone in 1915, graphically portrayed this relation in a chart of overlapping circles whose centers were arranged in a straight line. The chief pathologic findings were grouped in a series along the straight line, ranging from palsy, through dropsy, cardiac weakness and degeneration, nerve degenerations, spongy gums, hemorrhages, bone lesions, to the lesions at bone ends which are so notable a feature of rickets and often of scurvy. The overlapping circles each of which embraced several of the pathologic series, began with classical beriberi and ranged through ship beriberi, scurvy, guinea pig scurvy, and infant scurvy to rickets.

There is little doubt that beriberi is a disease group and not a fixed disease entity. The same is unquestionably true of scurvy and doubtless the other food deficiency diseases will eventually appear as types, varying with the relative imbalance of vitamins, and modified by other nutritional and environmental factors. As has been indicated, scurvy and beriberi have many points of pathologic similarity. Among these are especially to be noted the nerve degenerations and enlargement of the right heart. Pellagra differs somewhat in having a triple complex in pathology and symptoms, involving nervous system, gastro-intes-

tinal tract and skin. It is of interest that scurvy often shows a reddened, roughened skin. The deficiency diseases are characteristically afebrile.

It is known that after eating buckwheat, many persons suffer from a severe dermatitis on exposing the skin to bright light. A similar explanation has been offered very plausibly for the rash in pellagra. It has been suggested, too, that the mental complex in pellagra is induced by bright light in a nervous system predisposed by a nutritional deficiency. The role of light, or actinic energy, in the causation and treatment of skin rashes, even in the acute infectious diseases such as smallpox, and scarlatina, is but poorly understood.

Darling found that in Rand scurvy, occurring with great frequency in South Africa and Rhodesia, there was a striking eccentric hypertrophy of the right heart, along with severe degenerations of the vagus nerve. Hess has noted the frequency of dilated right heart in infantile scurvy. There is often also associated a cardio-respiratory disturbance which still further illustrates the involvement of the nervous system. Such findings indicate a close relation between scurvy and the beriberi group. Darling calls attention to the contrast between beriberi as a neuro-cachexia, and rickets as an osteo-cachexia.

Vitamins and Diet

The fat soluble vitamins are found abundantly in butter, eggyolk and cod liver oil. The water soluble vitamins are found in yeast, and in many green vegetables and whole grains. There is reason for believing that vitamins can not be constructed either by animals or by plants, but that they are a product of bacterial action. Their presence is necessary for the growth of yeast and the rate of yeast growth has been used as a measure of the quantity of vitamins present in food substances. Vitamins are destroyed by heat, either excessive or of moderate intensity but long continued.

An interesting study of vitamins in bread was made by Voegtlin, Sullivan and Myers, of the U. S. Public Health Service, in connection with investigations on pellagra. They were impressed with the marked reduction in two decades of the vitamin content in the dietary of the population studied (Spartanburg county, South Carolina). They ascribed this reduction to three causes. First, reduction in usage of vitamin-rich foods such as fresh meats, eggs and milk, due to advancing cost. Second, increased use of highly milled cereals, made from wheat and corn, in which the vitamin-rich pericarp, husk and kernel are largely removed. Third, the increased use of baking soda in bread-making. The danger from soda lies in the fact that too often it is used to raise bread in place of yeast, and is not neutralized by acid as with sour milk. The soda apparently destroys the vitamin of the grain and this increases the deficiency of the excessively

milled grain. The use of soda to soften beans and other foods in cookery, has an equally destructive result.

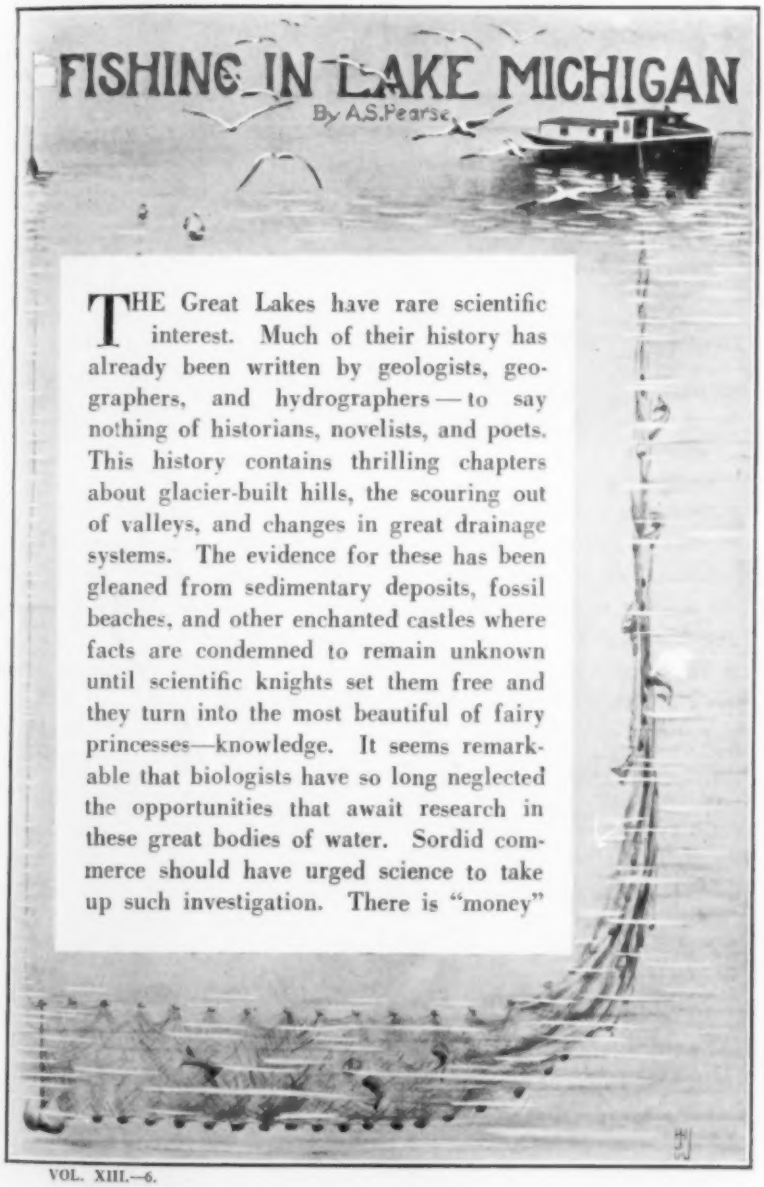
It is evident that the use of highly milled grains is to be condemned. The extensive utilization of whole grain products during the war was a most beneficial modification of our national dietary, and should be continued. Its benefits pertain to the stimulating effect on the teeth, the avoidance of a concentrated and costive diet, and the provision of more vitamins.

Under ordinary circumstances no particular attention is required to the practical details of securing sufficient vitamin content in the dietary of the average individual in this country. But in the endemic pellagra district, or where for any reason a varied supply of fresh foods is not to be had, the securing of the necessary vitamins becomes a matter of concern. Such a diet should include yeast bread made from the whole grain. If rice is used to any considerable extent, it should be undermilled, with a high phosphorus fraction. At least once weekly, legumes such as beans or peas should be served. Fresh fruit and vegetables should appear several times a week. Barley is especially desirable and should be added to all soups. Yellow or water ground cornmeal is preferable to the white variety. White potatoes and fresh meat also should be included at least weekly, and better once daily. So far as possible canned food should be discarded.

It may not be amiss to warn against commercial preparations of vitamins which are beginning to appear on the market. Under ordinary circumstances of life there is no need for such preparations. It is questionable whether any circumstances at present justify their use. Further than this, the chemical instability of vitamins makes it difficult to say under what conditions of preparation and preservation, their potency will be maintained. Then, too, since there is no approved method of standardization of vitamins, there is consequently no check on adulteration of commercial preparations. It seems probable that the appearance of vitamin preparations on the market, coupled with the present scientific and popular interest in the subject, will lead to an exuberant advertising campaign parallel to the exploitation of starch-free foods for diabetics. Among these latter, a small minority alone are found on analysis to be what they claim.

Conclusion

In summary, a new and important chapter is being written in our knowledge of nutrition, and to the classical requirements for a balanced dietary, has been added the requirement of a group of substances called vitamins. Vitamins are essential for growth, maintenance and reproduction of the human body, and lack of them leads to definite disease on a basis of mal-nutrition.



THE Great Lakes have rare scientific interest. Much of their history has already been written by geologists, geographers, and hydrographers — to say nothing of historians, novelists, and poets. This history contains thrilling chapters about glacier-built hills, the scouring out of valleys, and changes in great drainage systems. The evidence for these has been gleaned from sedimentary deposits, fossil beaches, and other enchanted castles where facts are condemned to remain unknown until scientific knights set them free and they turn into the most beautiful of fairy princesses—knowledge. It seems remarkable that biologists have so long neglected the opportunities that await research in these great bodies of water. Sordid commerce should have urged science to take up such investigation. There is "money"

THE MACHINE FOR HAULING NETS

in the Great Lakes, and commerce must always depend on science for the exploration, conservation and improvement of its resources. The fisheries of the Great Lakes bring in more than ten million dollars each year and the chief contributors are Lake Erie and Lake Michigan.[1]

The men who fish in the Great Lakes have the picturesqueness which is characteristic of deep water fishermen the world over. The danger and uncertainty of "open water" fishing give it the touch of romance that attracts bold spirits who like to take chances. The life is hard, but it may, and usually does, give rich rewards to those who follow it with industry, courage, and common sense. Fishermen are often "rough on the outside", but their life and training make them honest, independent and usually more thoughtfully courteous than those who have acquired "polish" in drawing rooms. One who has fished for a livelihood seldom goes back to the humdrum of a safe life on land. To give some idea of what a fisherman does each day on Lake Michigan the following description of a trip that the writer took as a guest on board the "Albert C. Kalmbach" is given:

On July 26 I got up at half past four and made my way through the deserted streets of Sturgeon Bay to the dock. A brisk wind was blowing in from Green Bay and the sky was overcast. Frank Higgins and his partner, Bill, were alrady loading boxes on board the "Albert C." when I arrived. "Boxes" are really trays and each holds about 1,600

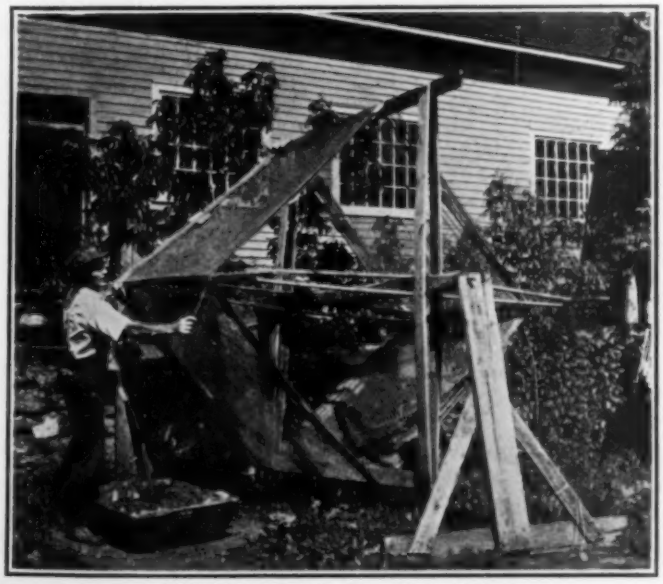
[1]According to the latest Report of the United States Bureau of Fisheries the value of the fisheries in these two lakes for the year 1917 was $4,332,767 and $4,038,927 respectively.

lineal feet of gill net. This morning the "boys" were loading "small mesh" nets, for they were going out after chubs and bloaters in the deepest part of Lake Michigan. As they worked I looked over the boat. The "Albert C." had been in the water less than two months and was a fine example of the type of boat now in growing favor with lake fishermen. Years ago fishing tugs were in common use. But tugs are expensive to maintain and, as fishermen to man them grow harder to find, they are gradually being superceded by little gasoline boats. The "Albert C." measured forty-five feet in length and had twelve feet of beam. In the center of her cabin was a shining new two-cylinder Kahlenberg engine which cost $2,500 and would delight the heart of any fisherman—a heavy duty engine; not speedy, but to be relied upon in a storm. Except for the little platform forward for the man at the wheel, the remainder of the cabin was devoted to fishing tackle. Oilskins and coiled lines hung on the walls and boxes of nets were piled on the floor aft. A gasoline hoist for hauling the nets occupied the space on the left side of the cabin forward.

As soon as the boxes were stowed Bill lighted the torches at the tops of the cylinders. When "she" was hot he "turned her over" and we started. We backed out of the slip just after five o'clock, went under the bridge, and set our course toward the head of Sturgeon Bay. A dirty fishing-boat named "White Swan" tried to race us, but Bill "let her out a notch" and we soon left the upstart behind.

"Ain't that an engine?" said Bill.

At a quarter of six we passed the lighthouse and were on Lake Michigan. A noisy flock of herring gulls greeted us. These birds fol-

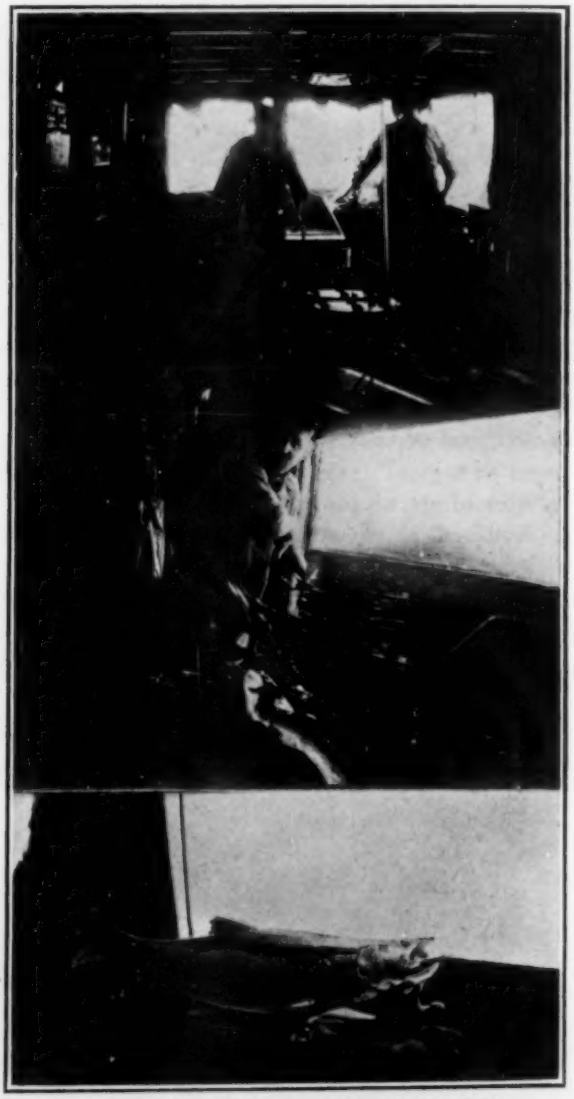


PUTTING THE GILL NET ON A REEL

lowed the boat all day, continually on the alert for fish or scraps. For nearly two hours Frank ran "NNE". It began to rain, the wind freshened and stirred up the lake. Toward ten o'clock, when we were about twelve miles offshore, Frank sang out:

"There's one'."

I peered in the direction he indicated but could see nothing. As we came close, however, I made out a couple of tattered squares of canvas waving from a pole which projected from the top of a wooden



A.

B.

C.

A—SETTING NETS OFF THE STEM OF THE BOAT
B—A TROUT JUST OUT OF THE WATER
C—A LAKE TROUT

buoy. The boys put on their oilskins. As the buoy came alongside Frank tried to haul it in, but the waves were too much for him, and he missed it. We circled around and, approaching from a little better angle, the buoy came on board. Bill quickly started the hoist, and Frank threw the line that had been fastened to the buoy over it. The way the little fingers on the hoisting wheel handle lines and nets is almost uncanny. The wheel is horizontal and as it revolves the fingers around its margin take hold on one side and let go on the other. When a line is placed over the wheel it is grasped and pulled across from one side to the other. In this way the line came into the cabin and brought up a "string" of nets from the bottom.

The nets that we pulled had been set for seven days at depths of sixty-five to eighty fathoms. All of them were tied together in "strings" of four boxes each. A line leading up to a flag buoy was attached at each end of a string. Gill nets stand up from the bottom like a tennis net; weighted along the lower side with leads and stretched by the pull of corks along the upper side. Fishes swim into the meshes while moving along near the bottom and become entangled. Most of those brought up in the nets are still alive. The deeper waters of lakes are usually cold and fishes may live for a long time after being caught.

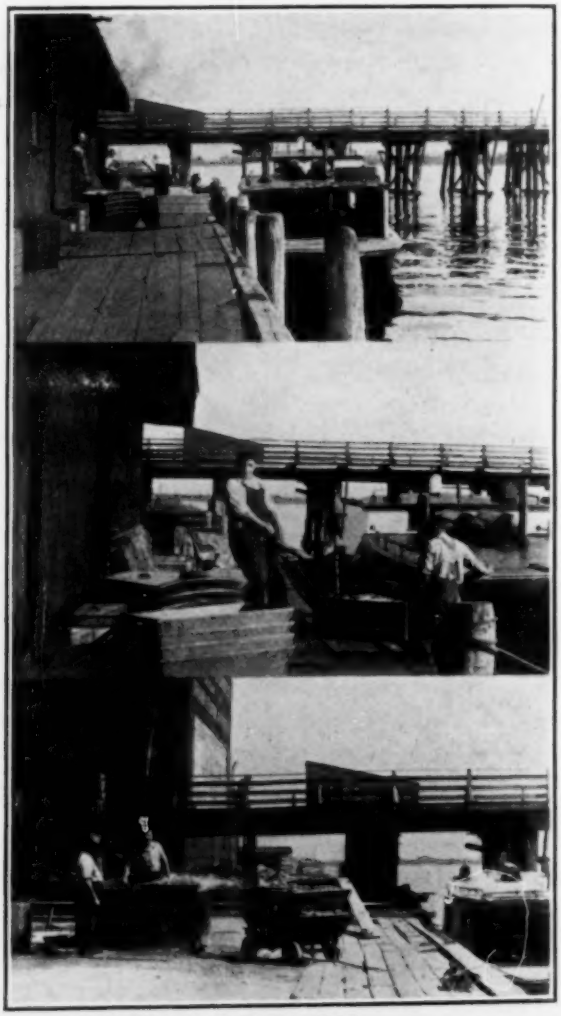
Bill stood by the port where the lines and nets came in and kept them running smoothly around the hoisting wheel. Frank dextrously took the fishes from the net, using a short awl in order to save his fingers from pricks and cuts. He also extracted cinders and twigs from the net before coiling it down in the box in front of him.

By half past twelve twenty boxes had been hauled and nets from the same number reset off the stern of the boat. The catch consisted of about 500 lake trout, 200 bloaters, 150 chubs, 12 lawyers, 2 blackfins, and 5 ugly little cottids, which the fishermen call "stonerollers". The lawyers, stonerollers, and a few of the other fishes were thrown back into the lake—to the great delight of the gulls.

I ate my lunch at eleven o'clock, but Frank and Bill did not get theirs until all the nets were set. On the way home Bill ran the boat, while Frank cleaned the catch. Frank performed his work with remarkable speed. Catching up a fish by its head, he laid it on a board; one movement with the knife removed the gills, another slashed open the ventral wall of the body, and a third threw out the visceral organs. At 3:10 P. M. we were back at the dock with the catch of the day cleaned and the cabin floor scrubbed.

I was glad to go on shore and rest, having lost my lunch in the lake, but the crew still had two or three hours work ahead. The nets had to be boiled, to keep them from rotting, and then spread on reels to dry. After that the nets to be set on the following day were to be wound off the reels into boxes. While the boat crew were looking after the nets, the men in the fish market sorted the fish and put them on ice.

Kalmbach's fish market, in Sturgeon Bay, is an interesting place. It is well equipped to care for all sorts of lake fishes and does both wholesale and retail business. The owner operates three boats which fish on a co-operative basis, the owner furnishing nets and boats and the crew getting a certain percentage of the catch. At the market fishes from pound nets are bought, mostly sheepshead and perch, and line fishermen bring in a number of pickerel each day. The retail departments sells fish to all who will buy—tattered urchins, pretty girls, hotel managers, dames in silken gowns come for fresh fish. Behind the market are three modern smoke houses where delectable chubs are prepared.



A—FISHING BOAT AT THE LOCK
B—UNLOADING BOXES OF LAKE FISH
C—BOILING NETS TO KEEP THEM FROM ROTTING

According to the Report of the United States Commissioner of Fisheries for 1918 the value of the equipment used for fishing in Lake Michigan in 1917 amounted to $4,038,927. This amount includes boats, nets, traps, lines, shore property, and the cash capital necessary for operation. The returns from the fisheries amounted to $2,270,859—a very fair amount for the capital invested. The fishes furnishing this revenue were as follows:

Fish.	Pounds	Value.
Trout, fresh	8,679,845	$856,228.00
Trout, salted	12,820	259.00
Ciscoes (chubs, bloaters, etc.), fresh	15,341,588	708,038.00
Ciscoes, salted and smoked	2,917,766	139,344.00
Whitefish, fresh	3,145,780	327,991.00
Whitefish, salted	28,048	2,174.00
Perch, fresh	2,361,071	116,419.00
Perch, salted	1,725	81.00
Suckers, fresh	2,103,163	74,803.00
Suckers, salted	14,110	625.00
Wall-eyed pike	132,024	18,445.00
Carp	246,503	7,500.00
Catfish and bullheads	164,466	6,627.00
Pickerel	40,597	3,375.00
Sturgeon, Caviar	346	904.00
Sturgeon	10,805	2,517.00
Crawfish	80,495	4,427.00
Lawyer	166,785	1,436.00
Rock bass	1,714	137.00
Buffalo	1,290	56.00

During 1917 the Great Lakes as a whole yielded $6,416,477 on a total investment of $10,732,879. In Lake Michigan fourteen-fifteenths of the product of the fisheries came from the species which were caught in deep water. In Lake Erie, which is shallower, more than half the value of the fisheries also came from deep water. These lakes are in marked contrast to those in the course of the Mississippi River (Lake Pepin, Lake Keokuk)[2] where practically all the revenue comes from shallow water fishes—carp, buffalo, dogfish, catfishes, sheepshead, etc.

The fishes in Lake Michigan, which are of most value commercially, not only live on or near the bottom in deep water, but secure their food there. The soft bottom ooze, directly or indirectly, supports many detritus-feeding crustaceans (Pontoporeia, Mysis), clams (Sphaeridae), and insect larvae (mostly those of midges and may flies). The ciscoes, which are the most abundant fishes, the little cottids, the long-nosed sucker, and the whitefish feed largely on this bottom fauna. The trout and lawyer are primarily fish eaters. All these fishes are true deep-water species which have not, in the long period since glacial times, migrated to any extent into small inland lakes or into streams. They are at home in the cool depths of large lakes—where there is always low temperature, great pressure, and little or no light.

[2]Annual Report of the United States Commissioner of Fisheries to the Secretary of Commerce, pp. 78, 79.

CLEANING FISH ON THE WAY HOME

In the shallow waters of Lake Michigan the yellow perch is the most abundant species. It is rather omnivorous in its food habits, and is at home in a variety of habitats. These characteristics probably account for its abundance, but for some reason it does not go into deep water. The pickerel and pikes, which are common, are fish eaters. The sheepshead prefers snails to other foods. The other shallow water fishes which are of commercial importance are dependent on aquatic vegetation and the small animals which live among plants for food. Where vegetation is plentiful, as on swampy shores and at the mouths of rivers, they are abundant.

The ability of any body of water to produce large numbers of fishes depends primarily on its food resources. Somewhere in the shore vegetation, or in the microscopic life of the open water, or in the soft bottom mud there must be sufficient quantity to permit many fishes to maintain themselves from day to day. In Lake Michigan the great bulk of the fish food is in or near the bottom mud. Lake Erie with its larger area of shallow water has a different ratio of food resources and supports more shore fishes.

Lake Pepin, which is really not a true lake, but an expansion of the Mississippi River, has quite different food resources for fishes. The temperature of this lake is rather uniform at all depths and varies markedly with the seasons. The bottom shifts continually and does not support an abundant fauna. There are none of the deep water

fishes of lakes here, but many species peculiar to rivers—spoonbill, redhorses, quillbacks, sand sturgeon, etc. The fishes in Lake Pepin feed more on the microscopic organisms in the water and the foods dependent on aquatic vegetation than those in Lake Michigan. This means that the food resources for the fishes that man makes commercial use of are not in Lake Pepin (or in the Mississippi River) itself but along the shores and in the tributary swamps and lakes. A river is a highway to feeding grounds in lakes, swamps, or other habitats where fish foods are abundant and many fishes pass through it. The open water of a large river contains food for fishes as microscopic plankton organisms which float in the water, but its bottom is rather barren. The plankton is derived largely from swamps, ponds, shores, and is not developed in quantity in open water.

The problems relating to conservation of the food resources of the fishes which have commercial value are not the same in Lake Pepin and Lake Michigan. Because the former resembles a river in being largely dependent on is tributary lakes and swamps for food, it has a more precarious food supply. Rainfall controls the height of its water and the availability of its food resources. If the swamps along the Mississippi are ever filled or drained to further agriculture, the fisheries must suffer. If the access of fishes to tributary lakes is cut off by dams, or if the value of the river as a highway is destroyed by the presence of the wastes of commerce in the water, fishes must decrease in numbers. The continued success of the fisheries of the Mississippi depends largely on the conservation of the habitats tributary to the river itself. The fisheries in Lake Michigan have greater hope of continued stability because the food resources of the commer-

KALMBACH'S FISH MARKET

cial fishes are in deep water, where they are less likely to be depleted or destroyed by civilization.

The quantity of food available limits the number of fishes that can exist in a given volume of natural water, but whether fishes grow to large size is dependent on other factors. Stagnation or continued movement of the water may make it impossible for fishes to take advantage of foods which might otherwise be available. Parasites may be so abundant as to kill fishes or impede their growth. To state the case briefly—the number of fishes that may *exist* depends largely on food resources, but ability of fishes to grow to large size depends on the opportunities they have to live a healthy, normal life and *grow*. In this connection true lake habitats appear to have the advantage over those of rivers in their stability. The bottom and the deep water of Lake Michigan are dependable; they can be counted on to furnish about the same amount of food each year and to offer safe retreats. The food for fishes in Lake Pepin depends on rainfall and varies in different years. The variation in the height of the water also makes conditions for breeding and shelter uncertain.

The inland fisheries of the United States constitute great natural resources which ought to be as carefully and as scientifically conserved as farm lands, forests or water power. Yet in proportion to their value, they have received comparatively little attention. There are stations for hatching eggs, and cars for distributing young fishes for stocking inland waters. There are several well-equipped stations for the investigation of problems relating to marine fisheries. For fresh-water there is only one station where scientific work concerned with fisheries is undertaken—on the Mississippi River at Fairport, Iowa. This paper attempts to point out that the fundamental problems relating to the conservation of lake fishes are different from those in rivers.

THE GULLS FOLLOW THE FISHING BOATS ALL DAY LONG

THE PROGRESS OF SCIENCE

THE UTILIZATION AND CONSERVATION OF THE NATURAL RESOURCES OF THE UNITED STATES

No part of the world is more richly endowed by nature with all that is necessary for the building of a great nation than the United States; where have these natural resources been used in a more wasteful and prodigal manner? Our nation has prospered, but at the expense of a much larger consumption and loss of its resources than was necessary, and we are now actually confronted with the question as to how long that which remains will avail to maintain us. Our civilization is as dependent on power, light, heat, metals, lumber and other material supplies, as it is on the air we breathe, and, if it is to endure, we must quickly recognize that the utilization of these necessities must be based upon the greatest economy compatible with effectiveness.

Reared in the midst of national abundance, the idea has become a matter of common expression that when our present resources are gone "something else will be found to take their place," or that because we have not as yet suffered for the want of any of them, the time will never come when the nation will suffer in consequence of our past and present prodigality. But whatever may be the advances of applied science, the resources that nature supplies will always be needed.

The natural wealth that we have inherited from the past is far from inexhaustible, and for this generation to pass away leaving a depleted heritage for those to come, with which to maintain and advance the civilization that we have here developed, would be a folly and a grievous iniquity.

Much that is called development is really destructive exploitation; much that we call production is really consumption; much that we call utilization is merely the sacrifice for small immediate profits of things that will be badly needed in the future. Nature has been so lavish with us that we have not felt the necessity of looking at these facts in their true light, but our nation and our civilization must have a future as well as a past.

It seems, therefore, to be an important duty of scientific men to disseminate information and instruction as to the real condition of our natural resources; to warn the nation where danger of exhaustion lies, and in the light of the best scientific and practical knowledge that we now possess, and through new researches directed to this end, to teach the ways in which our resources may best be maintained. These great economic problems are so involved with industrial, financial and political questions that little direct influence can be exerted without a long educational campaign. This will in time bear fruit, but the longer the time that will be required, the more important is an immediate beginning. Exact scientific knowledge alone can guide in this large field, but even science can not take care of industrial waste. Such correction can be made only by an enlightened moral sense.

THE EXECUTIVE COMMITTEE ON NATURAL RESOURCES

At the instance of the National Academy of Sciences, a committee of that body, and similar committees appointed by the American Association for the Advancement of Science and the National Research Council have held two meetings at the American Museum of Natural History in New

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JAMES ROWLAND ANGELL

Installed on June 22 as President of Yale University. Dr. Angell has been professor of psychology and dean of the faculties in the University of Chicago. During the past two years he has served successively as chairman of the National Research Council and president of the Carnegie Corporation

York City, to consider the status, utilization and protection of our natural resources. This joint board, which has been authorized to assume the name of the Executive Committee on Natural Resources, plans to promote the scientifically directed effort and education for the most efficient and advantageous use of our natural resources.

The committee plans the appointment of a paid executive and the necessary clerical force, with an office in Washington. Immediate steps will be taken to secure the cooperation of as many as possible of the educational and scientific institutions of the country. The committee will not duplicate the work of any existing organization; its purpose is to help them in securing better support. In the matter of correcting and furthering legislation that may bear on the subject of our natural resources, the committee expects to provide the facts and information and furnish a broad scientific basis for State and Federal action, keeping free from specific legislative problems.

This Executive Committee on Natural Resources lays claim to public confidence, as it is composed of scientific men of standing, representing the leading scientific organizations of the country. It is hoped that among the great body of patriotic and public-spirited citizens, there will be many to join in ensuring the initiation and maintenance of the work of the committee by their moral and financial support and encouragement, or by personal work for its success.

The following is the present membership of the committee:

Representing the National Academy of Sciences

John C. Merriam, President, the Carnegie Institution of Washington; John M. Clarke, Director, New York State Museum; J. McKeen Cattell, Editor, *The Science Press.*

Representing the National Research Council

John C. Merriam, John M. Clarke, J. McKeen Cattell, Vernon Kellogg, Secretary, National Research Council; C. E. McClung, Director, Zoological Laboratory, University of Pennsylvania.

Representing the American Association for the Advancement of Science

John C. Merriam, Henry S. Graves, Former Chief, U. S. Forest Service; Isaiah Bowman, Director, American Geographical Society; Barrington Moore, President, American Ecological Society; V. E. Shelford, Professor of Zoology, University of Illinois.

Chairman, John C. Merriam.

Vice-chairman, John M. Clarke.

Secretary, Albert L. Barrows, National Research Council, 1701 Massachusetts Avenue, Washington, D. C.

Assistant Secretary, Willard G. Van Name, American Museum of Natural History, New York, N. Y.

MME. CURIE'S VISIT TO THE UNITED STATES

The events arranged in honor of Mme. Curie have been fully reported, but it may be desirable to place them in consecutive order for permanent record.

Mme. Curie first visited Smith and Vassar colleges. On May 17 she was given a luncheon in New York by the American Chemical Society, the American Electrochemical Society, the Chemists Club and American sections of the Société de Chimie industrielle and the Society of Chemical Industry. In the evening a reception in honor of Mme. Curie was given at the American Museum of Natural History by the New York Academy of Sciences and the New York Mineralogical Club.

On Wednesday afternoon the American Association of University Women welcomed Madame Curie in Carnegie Hall. Addresses were made by Dr. Florence Sabin, professor of histology at the Johns Hopkins University, and Dr. Alice Hamilton, of the Harvard Medical School. President Pendleton, of Wellesley College, announced the award to Mme. Curie of the special Ellen Richards Research Prize of $2,000. On Thursday

PRESIDENT AND MRS. HARDING WITH MME. CURIE AND HER DAUGHTERS AT THE WHITE HOUSE

evening, at a dinner given in her honor by the National Institute of Social Science, the gold medal of the society was presented to her.

The gram of radium valued at $120,000, a gift from the women of America, was presented to Mme. Curie by President Harding on May 20. M. Jusserand, the French Ambassador, made a brief introduction. After the presentation Mme. Curie responded as follows:

I can not express to you the emotion which fills my heart in this moment. You, the chief of this great Republic of the United States, honor me as no woman has ever been honored in America before. The destiny of a nation whose women can do what your countrywomen do to-day through you, Mr. President, is sure and safe. It gives me confidence in the destiny of democracy.

I accept this rare gift, Mr. President, with the hope that I may make it serve mankind. I thank your countrywomen in the name of France. I thank them in the name of humanity which we all wish so much to make happier. I love you all, my American friends, very much.

In the evening at a meeting held under the auspices of the U. S. National Museum, Miss Julia Lathrop extended to Mme. Curie greetings, and Dr. Robert A. Millikan, of the University of Chicago, gave an address on radium, describing the researches that led to its isolation by Mme. Curie. On the following day Mme. Curie set in motion the machinery of the new low temperature laboratory of the Bureau of Mines, which is dedicated to her.

The following week Mme. Curie visited the laboratories at Pittsburgh where was refined the gram of radium presented to her.

Subsequently Mme. Curie visited the Grand Canyon and Yellowstone Park. Returning to Chicago, the Wolcott Gibbs medal was conferred on her by the Chicago Section of the American Chemical Society, and she was entertained by the University of Chicago and by the Associated Women's Organizations. After a visit to Niagara Falls and a reception at Buffalo, she proceeded to Boston, where among other functions a dinner was given in her honor by the American Academy of Arts and Sciences. Mme. Curie then planned to visit New Haven to be present at the installation of President Angell on June 22. She expected to sail with her daughters for France on June 25.

EXCHANGE OF PROFESSORS OF ENGINEERING BETWEEN AMERICAN AND FRENCH UNIVERSITIES

There has been for some time a regular annual exchange of professors between individual universities in France and America in regular academic fields, such as literature, history, law, fine arts, economics, etc., but no such exchange in engineering or applied science. These subjects are taught in France under special faculties, not included in existing exchanges with America. Furthermore, the French methods of teaching these subjects are unlike our American methods, for various reasons, based on the history, traditions and sociology of the two countries. The war showed the importance of engineering in production and distribution, and the many ties of friendship which bind us to France depend in various ways upon applied science. It should therefore, be to the mutual advantage of France and America to become better acquainted with each other's ideals and viewpoints, in the study and in the teaching of these subjects.

With these purposes in mind, the late Dr. R. C. Maclaurin, in 1919, as president of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to coöperate in a joint exchange of professors with France, on a plan definitely outlined. Their replies being favorable to the project, a committee was appointed, with one member from each of the seven institu-

tions, to report on the plan, and on methods of carrying it into effect. The committee met in December, 1919, and ratified the coöperative plan with some few modifications. The present president of the committee is Director Russell H. Chittenden, of Yale University, and its secretary Dean J. B. Whitehead of the Johns Hopkins University.

Since the Institute of International Education, in New York, concerns itself with the interchange of college students and teachers from all parts of the world, the committee requested the director, Dr. Stephen P. Duggan, to undertake the negotiations between the committee and the French university administration. The French administration responded cordially to the offer for the annual exchange of a professor. The French have selected, for their first representative, Professor J. Cavalier, rector of the University of Toulouse, a well-known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year, among the seven coöperating institutions, namely, Columbia, Cornell, Harvard, Johns Hopkins, the Massachusetts Institute of Technology, Pennsylvania and Yale.

The American universities have selected as their outgoing representative for the same first year (1921-22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

SCIENTIFIC ITEMS

We record with regret the death of Edward Bennett Rosa, chief physicist of the Bureau of Standards and of Abbott Thayer, the distinguished artist. Readers of this journal will remember Dr. Rosa's recent article on the economic importance of the scientific work of the government and Mr. Thayer's articles on protective coloration.

The Royal Society has elected as foreign members Dr. Albert Calmette, of the Pasteur Institute; Dr. Henri Deslandres, of the Paris Observatory; Professor Albert Einstein, of the University of Berlin; Professor Albin Haller, of the University of Paris; Professor E. B. Wilson, of Columbia University, and Professor P. Zeeman, of the University of Amsterdam.

Professor Albert Einstein sailed for Liverpool on the *Celtic* on May 30. He has since delivered the Adamson lecture of the University of Manchester and given lectures at King's College, London, and other institutions.

A commission of five engineers has been appointed to visit England in June to present the John Fritz medal to Sir John Hadfield, in recognition of his scientific research work. The members of the commission are as follows: Dr. Ira N. Hollis, president of Worcester Polytechnic Institute; Charles T. Main, of Boston, representing the American Society of Civil Engineers; Col. Arthur S. Dwight, of New York, representing the American Institute of Mining and Metallurgical Engineers; Ambrose Swasey, of Cleveland, of the John Fritz medal award board and the American Society of Mechanical Engineers, and Dr. F. B. Jewett, of New York, of the American Institute of Electrical Engineers.